DISCOVERY

PAPER ECONOMY
Reduced in thickness, but not in contents. Approximately 30,000 words in each issue.

OCTOBER
1945

1/6

A Time

BECAUSE
the atomi
pulsion to
"atomic p
bombs sti
tinued thi
informed
dentally ca
Dr. H. D
is publishi
The cor
stinctively
symbols n
next. The
to order c
Dr. R. R
technique
trivial com
power sha
certainty t
power is c
production
solve. Bu
indeed un
bombs has
On refle
cumstance
United Sta
America a
necessary
important
get scienti
her fronti
States, but
ment with
Nations e
clearly tha
released by
War Infor
prepared a
the United

DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

October, 1945 Vol. VI No. 10

EDITORIAL OFFICE: 244 HIGH HOLBORN, W.C.1 Tel. Chancery 6518
PUBLISHED AT THE EMPIRE PRESS, NORWICH, ENGLAND Tel. 21441

The Progress of Science

A Time for Greatness

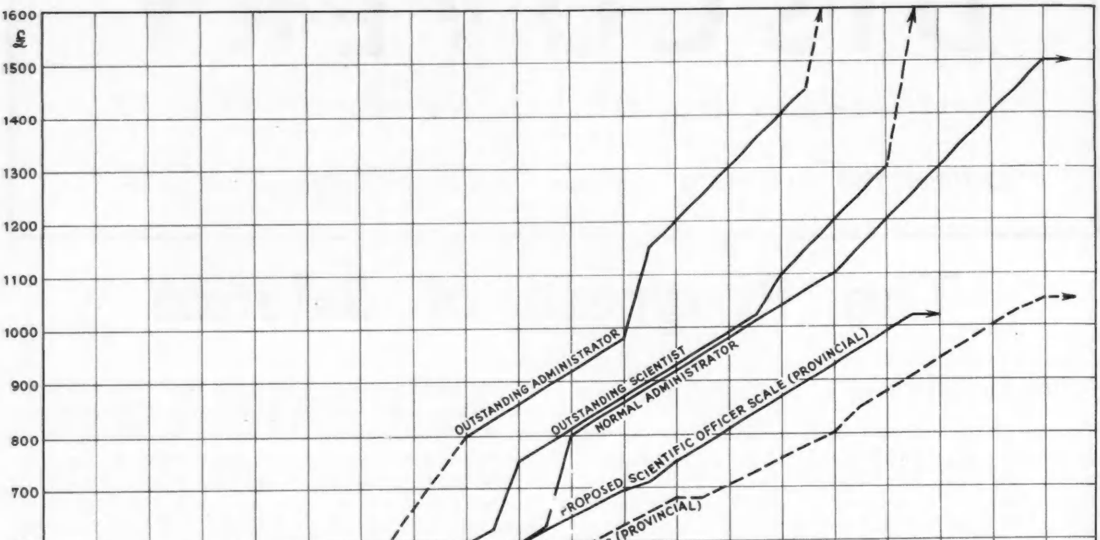
Because of the excessive defeatism and cynicism that the atomic bomb has aroused we feel a moral compulsion to devote more precious space to the subject of "atomic peace". Atomic bombs, and rumours of atomic bombs still more horrific than those used already, continued this month to be discussed by informed and ill-informed people alike. (Several atomic rumours incidentally can be either confirmed or dispelled by consulting Dr. H. D. Smyth's report which H.M. Stationery Office is publishing in this country.)

The common man has recognised, though almost instinctively, one feels, that Hiroshima and Nagasaki are the symbols marking the gateway between one era and the next. The new age is one in which "our only hope is to order our lives so as to avoid war", as one scientist, Dr. R. R. Nimmo, has put it. Discussion about the technique of making and detonating an atomic bomb is trivial compared with the burden of ensuring that atomic power shall be made safe for the world. For it is a cold certainty that every country capable of developing atomic power is capable of making atomic bombs. Indeed the production of an atomic bomb is the easier problem to solve. But development of atomic power will be perilous indeed until a wise international decision on atomic bombs has been made.

On reflection it would appear that the historical circumstances were such that in no other country but the United States could a bomb have been made in 1945. America alone had the necessary labour reserves and the necessary industrial capacity; what is probably more important she had the political power that was needed to get scientists of other countries to come to work within her frontiers. The bombs were made in the United States, but not by an all-American effort. The achievement within the United States was essentially a United Nations effort. That point should have emerged more clearly than it did from the statements on the bomb released by the Ministry of Information and the Office of War Information. (A joint statement should have been prepared and agreed for simultaneous release in Britain, the United States and Canada, and throughout the rest of the world.) It was a pity too that Britain did not receive the credit—including financial credit even—due to her for the magnificent contribution to the allied cause made by our brilliant scientists and technicians.

But these considerations pale into insignificance when one gets down to thinking about the rock-bottom questions involved. *How could we "outlaw" the atomic bomb?* Temperament rather than hard reason may satisfy us that the atomic bomb can be outlawed. If we don't believe that to be possible then we must ask, *How can we ensure that the capacity to make atomic bombs in quantity shall remain under the control of a United Nations Security Council, and how do we ensure that the bomb shall never be used except to enforce international law?* One would like to believe that the whole of mankind can be convinced that the atomic bomb has made war absurd, for universal realisation of that point would mean that universal disarmament would lie within the realms of possibility. But we cannot bury our heads in the sand; we have to face up to the dread prospect that one day it may become necessary to drop one atomic bomb or several atomic bombs for the terrible purpose of bringing to her senses a nation hell-bent on aggression. One shudders at that prospect but the weapon with which to arm an international police force (which many people advocate) is bound to be of a very different order from a truncheon or a machine gun or a "block buster".

The common man realises, only vaguely perhaps, that control will necessitate revolutionary plans—and enforcement of those plans. But he needs guidance and some of that guidance must come from scientists. We use the word "revolutionary" advisedly but with some misgivings. We do not wish it to be taken that we support the idea of an "open conspiracy" of scientists, the open conspiracy that H. G. Wells conjured up in more than one of his books. Democracy cannot be forced into liquidation to be replaced by a benevolent technocracy. The benevolent technocracy is a mirage, a dangerous mirage, that must be dispelled. There has been much talk trending towards such a form of government; most of it has occurred behind closed doors but some of it has emerged into the light of print. One science writer, we note with regret, has even welcomed the trend.



The graph gives at a glance an indication of the extent to which the salaries of Government scientists will be improved if the proposals in the White Paper are adopted. It can be seen that the average administrator would be about as well paid as the outstanding scientist, whose prospects are seen to be inferior to those of the outstanding administrator. The bottom line shows the present salary scale.

This is a time for greatness. The scientists of Britain and the other leading humanitarian countries must rise to their full intellectual stature and give the lead which the occasion demands. Our fullest admiration goes out to Professor M. L. E. Oliphant who with great courage has ignored the ban on free speech which seems to be the price too often paid by scientists for taking part in war research. More than that, he has staked his scientific reputation on certain forecasts; but whether these forecasts prove right or wrong he has rendered great public service. We hope that others will follow his lead, and that of Professor A. V. Hill, for the public is still ignorant of the terrible issues at stake.

President Truman's statement to reporters on October 9 shows that the American public, too, is either not alive to these issues or, if it is alive to them, has not impressed its opinions on Senate and Congress. The former is more likely to be the case.

Better Pay for Government Scientists

Sedulously over long years the Treasury has built up for itself a great reputation of miserliness. Rarely in the past did it do anything to damage that reputation when it came to dealing with the financing of Government scientific work. Admittedly the character of such work must have been difficult for any Treasury official to appreciate; as one distinguished Government scientist put it, with charitable moderation, "The difficulty of working a scientific establishment as part of a public office is to exercise control whereas the primary duty of a scientific establishment is experimental initiative, which to any controlling authority must have something of rash speculation about it." When, during the war, the Treasury lost some of its grip, Government science emerged unstunted from the shade of penury and blossomed forth with a multitude of remarkable achievements that contributed

much to making victory possible. It is not necessary for us to expatiate on the long line of scientific successes—radar can suffice as an example—for which Government scientists are entitled to a large share of the credit. The results of the spectacular projects speak louder than any publicist. We believe, too, that the public has also come to recognise that a major factor behind the perhaps more pedestrian but no less important achievements of the Ministries of Food, Agriculture and Health has been the work of scientists in Government employ.

The problems of the reconstruction period that will demand research and development work in Government establishments will be no less numerous than those thrown up by the war. It is imperative that the Government scientific service should be the best possible; it is vital that it should be able to attract and retain its due proportion of the best scientific brains. It is no less important that the scientists should be given every opportunity so that they can accomplish first-class scientific work.

The ending of the war saw the exodus begin of scientists from Government service; to a degree this was inevitable for the staffs of Government laboratories had been inflated to meet war-time needs, but there is no doubt that many scientists were leaving for the reason that industry and universities offered more attractive prospects. Now the Government has stepped in with proposals that should check the flow which showed signs of increasing and might have reached the point where the efficiency of the Government scientific service would have been jeopardised. The proposals should do much to ensure that scientists will put Government science alongside industry and university when considering their peace-time careers. A White Paper with the title *The Scientific Civil Service* has been published (Stationery Office, Cmd. 6679, price 3*d*.), setting out a number of measures for "reorganising" the Government scientific service. Recruitment is another aspect treated in the document.

The Government proposals incorporate some of the recommendations made by a Treasury committee set up more than two years ago under the chairmanship of Sir Alan Barlow and including Sir Edward Appleton (secretary of the Department of Scientific and Industrial Research), Mr. W. F. Lutyens of I.C.I., and Professor E. K. Rideal, the colloid chemist. The investigation carried out by the committee was made confidential (believe it or not, because results were wanted quickly!); this explains why copies of the Barlow Committee's report have been circulating privately for many months whereas it has only just been made public—as an appendix, printed in small type, to the White Paper.

A major point made in the Barlow Report was "that the Government failed in peace-time to attract into and retain in its service a proper proportion of the best scientists produced by the universities." The fault, the report says, lies partly in the standards of remuneration and prospects offered. The Treasury has taken note of the point, and suggests improved salary scales. The order of the improvement can be seen at a glance from the graph published on this page.

The Barlow Committee expressed itself concerned not so much with the pay and prospects of the average scientist ("for scientists of average ability the prospects offered by Government employment, at any rate up to a certain level, have not compared unfavourably with those offered in most universities and in industry") but with the failure of Government service to attract the outstanding scientist. The committee argued that a first essential would be to ensure that the best scientists have prospects as good as those of the best men in the administrative side of the Civil Service. The Treasury half accepts this and its proposals go part-way towards meeting this particular need.

Another recommendation of the Barlow Committee was that an Interdepartmental Scientific Committee should be set up. The committee would keep under review the efficiency of the Government scientific service. Here the Treasury has agreed; such a committee will be set up under the chairmanship of the Secretary of the D.S.I.R., and comprising the heads of all scientific directorates and departments; the committee will include administrative (non-scientific) officers and its secretary will be a Treasury official.

There will be plenty of things for the committee to look into. The two pages of the Barlow Report on general conditions of service contain many suggestions that the interdepartmental committee must get implemented—recommendations for extending contracts with industry and universities, increasing liaison between Government scientific branches, eliminating unnecessary secrecy, and so on. The committee can do much towards securing some uniformity of standards; having grown up in a piecemeal fashion, the service bears every mark of its haphazard growth; every new kind of expert needed meant the creation of a new grade so that there are to-day over 500 scientific and technical grades, and the interdepartmental committee's first job might well be to try to effect some sense of order by reducing that number to a reasonable and functional figure. On the subject of secrecy it is unnecessary to say much; it is well known that a predilection for excessive secrecy has long existed, and there is at once irony and despair in the words of the Barlow Report—"*it should not be assumed as a matter of course . . . that the work of a Research Establishment must automatically be regarded as secret.*"

Centralised recruitment for the service is to be started, The whole of the scientific service will be recruited through the Civil Service Commission and Dr. C. P. Snow (a former editor of DISCOVERY) has been invited to advise on the recruitment of Scientific and Experimental Officers. Entry to these grades will be competitive, on the basis of educational record and experience, together with an interview; minimum educational or technical qualifications that candidadtes must possess will be publishe soon. Some vacancies will be kept open for Servicemen, and it is to be hoped that their allocation will be a generous one for the number of scientists who have spent this war in uniform doing non-scientific jobs is larger than is generally recognised.

Reorganisation must be beyond altering the names of half the grades in the scientific Civil Service and bringing the financial rewards more in line with what Government scientists deserve. The aim must be to ensure that Britain has a state scientific service second to none. That will depend to a large extent upon whether the Treasury is far-sighted enough to deal generously with science and scientists. A revolution in the Treasury's attitude to

scientific work is a first essential. Anything less than that and we are back where this note began.

The proposals have had a very mixed reception. They have been welcomed in one breath, and criticised in the next. We are doubtful whether they are likely to be adopted as they stand. Parliament has the opportunity of improving them, and it is to be hoped that the Chancellor of the Exchequer will take full notice of Professional Civil Servants who regard the proposals as a betrayal of earlier Governmental premises.

The Mind of the Soldier

It was during the first World War that it first became apparent to the military authorities that soldiers had minds of their own which must be considered. Before that time the conception of soldiering mentality was a sort of hangover from swashbuckling days: officers must be good chaps with dashing personalities and a good leg for a boot, and preferably not too intelligent. Other ranks had to do what they were told without question and had no need to think for themselves. Courage or the lack of it was a moral consideration, and a failure of courage was a crime punishable as such.

The first World War introduced conscription in Britain, in a form which meant the sudden transition of all types of men, with very little mental selection (and not overmuch physical selection), from civil life to the front line often in a matter of a few weeks. The outcome was the appearance of that was first known as shellshock, and thought to be due to the shock of close heavy explosions, a condition later recognised as "battle neurosis" which might occur among men in base camps who had never been in the front line.

After the war a Committee of Enquiry into Shellshock was set up by the War Office and in its report, published in 1922, there occur the following remarks:

> It is clear to us that during 1916 and 1917 the question of the "condition of the nervous system" of the recruit did not receive adequate consideration either in the instructions to recruiting medical officers by the military authorities or in the minds of the officers actually engaged in the medical examination of recruits, though recruits with gross nervous defects, e.g. having been certified insane, or with epilepsy, were rejected when these defects were ascertained. Generally, the evidence we have heard has convinced us that enough attention is not yet paid to the mental and psychological aspects of military service.

This quotation is given in a book entitled ***The Shaping of Psychiatry by War***, by Brigadier John Rawlings Rees (Chapman and Hall, 10*s*. 6*d*.). The title seems a little forbidding, but the book itself, which is based on the Thomas W. Salmon Memorial Lectures given under the auspices of the New York Academy of Medicine, is so well written, and so apposite to the personal experience of so many people during the war, that it is certain to be of very considerable interest to a very much larger audience than is normally interested in medical literature. The quotations are of importance because they do seem to express some of the basic problems which have been solved during the second World War by the army psychiatrists who came to be described by the vivid, and perhaps not unaffectionate, term of "trick-cyclists".

Brigadier Rawlings Rees has a lot of fascinating things to say about a lot of fascinating subjects, and it is impossible to do more than to refer to a few of them here.

One of the most important topics concerns the selection of personnel. He remarks at one point that it would be ideal if every man taken into the army to fight or to service front-line troops could be entirely fit, and have an intelligence quotient of well over 100. This has now been generally realised, as can be seen from the remark of a colonel of the Red Army medical service *—There is no place for any dull men in the modern army, we keep them out, or if they get in we send them back to industry at once.* Brigadier Rawlings Rees is, however, no mere militarist blind to larger issues, and his sentence, "It is a worrying thought that our best men have to be killed in battle or in many cases mentally broken by their experiences while the inadequate remain unscathed at the base or at home," is a good index to the tone of his book. However, once a war has come, the best men must be selected for the dangerous jobs, and dullards or unstable men will not only crack up themselves, but endanger their comrades in doing so. The man who is breaking down with acute anxiety is very bad for his unit and is likely to "infect" other men.

The importance of intelligence and the consequences of putting a man to a job beyond his intellectual capacity are illustrated by the following: "The dullard amongst men of higher intelligence begins quickly to feel inferior and from this he develops anxiety; he may break down or he may malinger, and . . . while malingering is extremely uncommon in this war, most of what there has been has occurred in dull men, looking for a way out of what is to them an intolerable situation. . . . A high proportion of absence without leave . . . occurs in dull men. The dullard becomes therefore in modern war a consumer of man-power rather than a contributor." Some of the lowest grades of intelligence have been put in the unarmed Pioneer companies, and there these one-job men have found their niche and have made, with pride, a valuable contribution to the war effort.

When the first few psychiatrists—and they were very few in numbers—came in contact with the army, they became somewhat unpopular, since their first task was to weed out all the unsuitable men who had escaped elimination by old-fashioned selection procedures. However, following the excellent advice set out by Brigadier Rawlings Rees on the way in which a psychiatrist should ensure that he fits into the army organisation, they have eventually gained for themselves a position of esteem.

However, the main work of the psychiatrist has not been concerned either with dullards or with humanising generals. One important task has been the establishment of selection procedures for officers in which the Penrose Raven progressive matrices test has been used as a means of testing intelligence. This consists of a series of figures or patterns with one missing, which is to be selected from a number of alternatives. The early ones are childishly simple: the later ones much more difficult and soluble only if the subject has learned from the earlier examples.

Brigadier Rawlings Rees has an interesting comment to make on assault courses. At first in some cases every endeavour was made to work up a feeling of hatred of the enemy but this artificial stirring up of hate defeated itself and led to a depressing reaction. In other cases the introduction to the battle course, using live ammunition, was so sudden that the men became frightened, and it was a

psychiatrist who devised the method of battle inoculation by slowly increasing "doses".

An amusing feature of officer-training with a psychiatric background was the pamphlet *Fifth Column Work for Amateurs* which explained, for example, how to damage trust in leadership, by several methods, including a display of officer privilege at a time when conditions for the men are bad; failure to explain the significance of orders, so that they appear inhuman and arbitrary; failure to explain sudden interference with leave or other privileges; and so on.

Finally in his chapter "The Way Ahead" (a title taken from an army film made to a psychiatric prescription) Brigadier Rawlings Rees has much to say which is of great value on the use of psychiatric methods for getting civilian life back to normal and for dealing with the psychological problems of the enemy countries.

Epidemic in Malta

THE issue dated January 1945 of the *Quarterly Journal of Medicine* contains a report by Seddon, Agius, Bernstein and Tunbridge on the epidemic of anterior poliomyelitis (infantile paralysis) which occurred in Malta during the winter of 1942 and the spring of the following year. Its interest for the epidemiologist is that the outbreak occurred in a small densely populated group of islands almost completely cut off from the outside world. For the non-medical reader the interest lies in the sidelights which it throws on the appalling conditions with which the population had to contend under almost continuous attack from the air and almost complete blockade.

Italy declared war on June 10, 1940, and Malta had its first raid the next morning, the beginning of an almost continuous series of attacks that lasted until late in 1942. The population crowded into cellars, crypts, large well-built buildings and, later, underground caverns. In January 1941 when the *Illustrious* reached Grand Harbour the raids were intensified and heavy damage was inflicted. In June 1942, Rommel's advance on Egypt meant a very dangerous lowering of food supplies, civilian rations being reduced to less than 1,500 calories daily, while the Service ration, although only about 2,300 calories, had to sustain men almost continuously engaged in heavy action.

Malta is about 16 miles long and has an area of 95 square miles. Across a strait some four miles wide to the north-west of Malta lies the island of Gozo with an ares just over a quarter that of the main island. These two islands had, in 1941, an estimated population of over a quarter of a million, living in an area less than that of the Isle of Wight, with densities of over 2,500 and 1,000 per square mile on Malta and Gozo respectively. In addition considerable numbers of men in all three Services had been landed on the islands.

By the summer of 1942 the water and sewage systems had been damaged and in some areas the local practice of using sewage as fertiliser for crops had had to be sanctioned officially. In any event it seems likely that the practice had already started in some areas where the sewage system had been destroyed. There was an epidemic of typhoid reaching its maximum in September 1942 and the use of sewage was discontinued, with one exception, in early November. By that time the raids had moderated in ferocity, and people were beginning to sleep in houses once more.

Poliomyelitis had been endemic in Malta but between the years 1921 and 1941 only 61 cases were reported. (The real number of cases must have been greater to judge by the incidence of effects of the disease among men in various age groups and by the fact that effects of late cases were not infrequently to be seen in the surgical departments of the civilian hospitals). No case was reported in 1942 before November 15 when the first civilian case appeared in Malta. The first case on Gozo came six days later, and the first Service case on the 27th. Altogether there were 426 civilian cases and 57 Service cases. The peak came towards the end of December with 108 cases in one week, and the epidemic was effectively over by early March. Over 80 per cent of the cases were children under five years of age.

In spite of the terrible conditions the mortality rate from the disease alone was only 3·5 per cent. while mortality from conditions aggravated by the disease only accounted for another 2·6 per cent. Apparently the strain of virus responsible was not the normal one for Malta, to which the inhabitants would have a certain degree of immunity; still less was it the strain to which the British service personnel had any immunity. In fact, although the Forces naturally did not include any of the juvenile age groups particularly vulnerable to the disease, the crude incidence of cases among them was 50 per cent greater than the case rates for Maltese or Gozitans who included large child populations.

Suspicion naturally fell on the possibilities of overcrowding, transmission by food or through contamination by sewage but none of these causes seems to have been substantiated. Although among some 370 families affected nearly half were sleeping six or more in a room at night, and although in 250 cases there were two or more people sharing a bed with a patient, there were only a handful of cases where two children of the same family were affected, and none where more than two were.

Contamination by food distribution has to be ruled out, and so has contamination by faecal matter, in spite of the fact that the virus can survive for more than 100 days in excreta. Most measures of water purification leave the virus unharmed, but no correlation of the outbreaks with damage to Malta's complicated water supply system could be traced. The crucial point seems to be the almost simultaneous outbreaks in Malta and Gozo which rule out most of the possible causes, including the possibility of contamination by flies, known as possible vectors of the disease. In fact, the first outbreak in Gozo occurred on the side of the island remote from Malta, and the only possible explanation seems to be transmission by carriers.

This could not be checked up without investigation, clearly impossible, of the movements of some 2000 people; nor—unfortunately, but not unexpectedly in view of the appalling conditions—was it possible to investigate with the necessary detail the period of incubation of the disease.

Inconclusive though the results may be, the report represents another stone in the monument to the courage and endurance of all those, living, working, and fighting in Malta, throughout what is possibly the most arduous siege in the history of warfare.

THE biologist who wrote this article was a lieutenant in the Oxfordshire and Buckinghamshire Light Infantry. He was captured by the Germans in June 1940 along with many other soldiers of the force known as "Davis Rifles", and spent five years as a prisoner of war. The observations he records here were made during his captivity.

The Life History of the Field Cricket

R. D. PURCHON, Ph.D.

WHITE of Selbourne wrote of crickets that each lived in its own burrow. This is true in general but my observations on a colony of field crickets (*Gryllus campestris*), in Oflag VII B at Eichstätt in Bavaria, showed that cohabitation occasionally occurs at all stages in their life history.

This was interesting: I tried to find further references to crickets in the natural history and scientific literature available. The result was astonishing, for in a learned work on insects it was stated that little was known of the life history and habits of field crickets. W. H. Hudson had little to say; W. P. Pyecraft in a book on the courtship of animals gave a brief quotation on the habits of the cricket, drawn from H. W. Bates's "The Naturalist on the Amazons". Research in the latter book revealed that Bates himself had not been the original observer.

I could find no record of close observation of crickets later than that by the Rev. Gilbert White in "The Natural History of Selbourne" (1787). Here, them, was a fruitful subject for research in the long hours of captivity, and all the more suitable since the colony of crickets in our camp was fairly large and the crickets could be easily approached.

The colony was situated on a steep bank facing due south and covered with a luxuriant growth of grasses, including Bromes, Fescues (Tall and Meadow), Tall Oatgrass, Cocksfoot and Meadow grasses. (I am indebted to Lieut. Andrew Biggar for this information.)

During the period from mid-May to the end of July adult crickets are abundant and the air is pierced day and night by their brisk chirpings; but let us begin their story at the beginning, from the eggs which the females probably lay in moderately large numbers in separate excavations in the surface of the soil.

In August the adult crickets have all died and their cheery though persistent notes have been replaced by the soft, easy wheezes of the Short Horned Grasshoppers in the grass, and the penetrating shrill of the Great Green Grasshoppers among the tomato plants and up in the lime trees. It is at this time that I first see the young crickets. They are about seven millimetres in length (excluding the long slender antennæ and the stiff caudal styles). At this stage in their life history the young crickets are extremely active and they jump about briskly when one tries to catch them. They live a nomadic life, for they have as yet no burrow into which to retire for protection. After a moult in September or October, the young crickets are conspicuously larger—body length 13 mm.—and I now found them actively moving over the grassy bank and occupying the burrows abandoned by their now deceased parents.

Until as late as mid-November movement was brisk on sunny days and the burrows changed hands frequently. On some occasions a large cricket was seen to evict a smaller one from its burrow, and on other occasions I have seen crickets abandon their holes, new tenants arriving in due course. Most of the burrows had but one occupant, but I observed one in which a pair—male and female—cohabited for several weeks.

I should here state that in the autumn, when the grass is short and the crickets are easily seen, it is possible to distinguish between the sexes, for the female possesses a short rudiment of her ovipositor between and below her caudal styles. In both sexes the wing rudiments are very short at this stage.

With the first frosts in mid-November the crickets with one accord set to improving their burrows, and fresh spoil was thrown out on to the platform of trampled earth at the entrance to each burrow. Throughout the winter the burrows remained open and on sunny days some of the occupants came to the entrances of their burrows and basked for a short time in the heat of the sun. Frequently they were so stiff with cold when they crawled out that they were incapable of defence and could be picked up without difficulty. After some time in the sun, however, they became quite active again.

It appears conclusive that throughout the winter the young crickets do not feed, nor do they moult. From November 5 until March 13, I observed crickets basking only on 32 days and then only for an hour or less, in the middle of the afternoon.

From the middle of March onwards I saw the crickets almost daily; I saw the first signs of feeding on March 16 (1945) and, on April 5, I confirmed Gilbert White's observations in finding a number of cast skins at the entrances to the burrows. The whole population moulted at about the same time, and I concluded from their appearance, that the crickets were now in their penultimate stage or instar. The wing rudiments were considerably larger, as was the ovipositor in the case of the female.

I estimated from a large count that this particular population of crickets consisted of about 600 specimens, at a density of approximately one per square metre. At the same time I made an estimate of the sex ratio, finding that the two sexes were present in approximate equality.

The final moult occurs in mid-May and in 1944 it was on May 14 that I first heard a cricket stridulate. Now, it is not commonly known how a cricket produces its song, or for that matter what is the distinction between a cricket and a grasshopper, so perhaps I had better expound on the subject.

The cricket is the first insect songster of the summer and is heard from mid-May until the end of July. His bright, cheery note cannot possibly be confused with the gentle

(*Left*) Adult male, stridulating. (*Centre*) Adult female, listening to the song of the male. (*Right*) Young female in spring, feeding.

soothing noise of the common grasshoppers, which only begins when the song of the cricket ceases. The stridulation of the Long Horned (or Great Green) Grasshopper is similar in timbre to that of the cricket, but since it comes after July and almost always from bushes or trees, no confusion should arise between the two.

Whereas the common grasshoppers produce their notes by rubbing their wing cases briskly with their thighs, in the case of the cricket the wing cases alone are used.

Let us sit on the bank and watch a male cricket singing (the female is silent). When we approach and sit down by the burrow, the alarmed cricket shoots head first into his home and only after four or five minutes does he make any tentative movements. First we see his tail and powerful hind legs; then, all being well, he emerges still farther and, turning suddenly, he retreats now tail first into the burrow. After a further short pause he advances slowly, waving his long agile antennæ before him.

Now we can see him clearly. He is a short, plump insect, almost an inch in length, very dark in colour but with a conspicuous yellow bar across the base of his wing cases. His head is large and broad, with great oval velvety eyes, and a multiplicity of sensory mouth parts and powerful jaws below. •Behind his head there is a broad segment—the thorax—and behind this his soft plump abdomen is protected above and at the sides by a pair of wing cases which are flat on top, the right overlapping the left.

On the femur of each of his forelegs there is a small oval silvery patch. This is his ear, or auditory apparatus. The centre pair of legs are about the same size as the forelegs, but the hind pair are large and well built, the second segment bearing a conspicuous array of sharp spines. Protruding from either side of the posterior end of his abdomen are two sensory caudal styles. Now let us watch him.

Out he comes on his platform, still partly hidden from us by overhanging blades of grass. Now he nibbles a cut piece of grass, pauses for a minute and slowly raises his wing cases to an angle of forty-five degrees with the long axis of his body . He opens them a little and then shuffles them from side to side, each movement producing a clear, penetrating note. His song is at first tentative and short but soon he warms to his theme, moving about as though dissatisfied with his position. As he moves the volume of his song varies according to the degree of concentration it receives from the funnel-shaped entrance to the burrow, thus producing a marked ventriloquial effect.

He looks for all the world just like some very skilfully contrived mechanical toy.

A foot to the right there is another cricket hole, but what is that strange insect standing impassively beside it? It is so utterly different from the creature we have just been scrutinising! It is a female cricket. She is conspicuously larger than her mate, her wing cases are browner and the yellow bar at the base is less marked. Her plump abdomen is endowed with a delicate felt of golden hair, and terminates posteriorly in a long black needle-shaped ovipositor; with this she buries her eggs in small excavations in the soil. Throughout her life she is silent, but she possesses an auditory apparatus on each foreleg and now she is listening entranced to the song of the male.

During their brief adult life the females may leave their burrows and, following the seductive music, seek for their mates. Then, living together in one burrow, what transports of delight are theirs before their brief honeymoon is ended!

Courtship

To study the courtship display of crickets more closely than was possible in nature, I captured a pair and kept them in a box on a bed of moist earth and covered with a glass lid. They were easy to look after, for all they required was an occasional sprinkle of water to keep the soil moist, and a daily supply of fresh juicy dandelion leaves, grass stalks, and an occasional freshly killed insect. It is best to arrange ventilation holes covered with perforated zinc or wire gauze, to prevent the glass becoming misty and thus hindering observation.

There is not space here to describe in detail the courtship of field crickets. I must merely record that the male courts the female with a special courtship song, which sounds like the sharpening of a pencil or the snipping of scissors, and by an ecstatic waving of the head and thorax. When they mate he is most attentive and caresses her abdomen with his caudal styles, and by brisk thrusts of his abdomen, until at length he transfers to her a strange object.

This object is a delicate capsule filled with spermatozoa and equipped with accessories which enable the female to hold it firmly. When the spermatozoa have been withdrawn by the female from the capsule into her body, she then discards the empty capsule. She may carry this capsule or spermatophore for a period varying from one to four hours, before she finally deposits it.

Mating is frequent during the short period of activity, and by the end of July eggs are laid, and the last notes of the dying crickets are fading away as the first trills of the grasshoppers are heard.

War-time Geology

W. D. EVANS, Ph.D., M.Sc., A.Inst.M.M.

As a result of over a century of research conducted by the Geological Survey and Museum and the geological departments of the universities, a vast store of information on the geology of Great Britain was available before the war. The information concerning resources of raw materials was destined to play an important part in the successful prosecution of the war against the Axis powers.

With the outbreak of war many commodities, formerly considered of second-rate importance, became vital to the country's war effort. A striking example is sand and gravel. "Ballast", as this is sometimes called commercially, was worked extensively before the war; but with the need for sand-bagging, the erection of concrete fortifications, and the construction of miles of runways for our aerodromes, it was required in increasing quantities in all parts of the country. London alone required well over 250,000 cubic yards of "ballast" for sand bags, concrete defence works, and air-raid shelters. To obtain this material from outside the Metropolitan area would have placed a tremendous burden on the sand and gravel producers and particularly on the rail and road transport system into the metropolis. In order to avoid this the Geological Survey was consulted. Two geologists were given charge of the problem, which was solved within two or three weeks by the location of sufficient sand and gravel within the Metropolitan area to supply the whole of London's needs. Using the six-inch to a mile geological maps of London they located suitable deposits of sand and gravel in parks and open spaces such as Hyde Park, Hampstead Heath and Gunnersbury Park. Pits were opened up in these deposits and the demand for sand and gravel satisfied without burdening unduly London's transport facilities. According to the estimates of the Civil Defence authorities the work of these two geologists resulted in a saving of £300,000.

A similar state of affairs prevailed throughout the remainder of the country. With the fall of France the whole of our 3,500 miles, or more, of coastline had to be manned with defence works, all of which required large quantities of concrete. Aerodromes were being constructed at a furious rate to accommodate our expanding air force in widespread and remote parts of the country. The result was that the 1937-8 output of sand and gravel —22,442,000 tons—was increased to at least three times this figure; hitherto unsuspected deposits were found and opened up to meet this urgent demand. Such deposits were located from the maps of the Geological Survey and each site checked and reported on by geologists in the early months of the war. In many cases long road-haulages were saved and the organisation of supplies, to fit in with the plans of the Air Ministry Works Directorate, was effected.

In addition to sand and gravel these vast enterprises required building and foundation materials in great tonnages. Loose rock rubble which was formerly considered more or less worthless became of first-rate importance, and acquired the commercial name of "hard core". It was required as foundation material for runways and buildings in clayey areas. The location of this material was an extremely difficult matter, but by the application of geological principles and the close study of the six-inch maps of the Survey, geologists were soon able to locate large areas of limestone and sandstone wherein the agents of denudation had disintegrated the "solid" beds of rock to rubble suitable for use as "hard core".

Strategic Minerals

From building materials our small band of trained geologists were constantly switched over to locate minerals urgently needed for war industries—minerals which formerly had been imported into the country. Germany soon controlled all the important European sources of minerals and her U-boats imperilled the shipping of heavy ores into the country. The high quality Swedish iron ore was soon denied to us, and imports from Spain diminished rapidly. We soon became dependent on the beds of low-grade ironstone of Jurassic age which extend through large parts of Oxfordshire, Leicestershire, Northamptonshire, Rutland and Lincolnshire. These beds of ironstone generally dip gently towards the east at angles rarely more than five degrees; but in many localities this dip is interrupted by small faults and other discontinuities. The simplicity of the geological structure of this great field of ironstone, however, lends itself to the development of large open pits from which the iron ore is extracted. This type of working, which is known as opencast mining, has been practised for over 50 years throughout eastern England, and during this period the pits have become more and more highly mechanised. This form of working bedded deposits calls for a precise knowledge of the geology of the area to be worked, as any discontinuity in the ore-bed, no matter how small, will seriously hamper the progress of the mechanical excavators that strip the overburden and dig out the ironstone. In pre-war days the planning of some of the pits was sometimes faulty owing to a lack of this detailed knowledge, so that with the need for expanding the existing opencast pits and the development of new ones, it became a matter of some urgency to institute a comprehensive geological survey of the field. This was a formidable task, as only a small unit of competent geologists were available for the work.

This unit, which rarely numbered more then seven, was sent out to make this detailed survey, which they accomplished; at the same time these geologists assisted the opencast mining engineers with schemes of exploratory boreholes and points of detail in the planning of new pits. Laboratory work of a detail character was also carried out in conjunction with the field survey on the petrology of the ore-beds. As a result it is now possible to distinguish, in what was formerly considered to be a fairly homogeneous bed of ore, the parts which are richest in iron and which will require the least amount of treatment at the furnaces. So successful was this co-ordination of the research-work

with the production side of this vital industry that the ironstone producers were soon in a position to meet all demands for iron ore. In 1938 the output of this ironstone (which rarely contains more than 40 per cent iron) was 10,726,000 tons, but by the end of 1943 this annual output had risen to 17,415,000 tons. In this way the country was made almost entirely independent of iron ore imports, and large areas of reserves have been proved by scientifically directed schemes of boreholes. War-time researches on behalf of this important industry will do much to maintain this expansion in the future. For example, it has been demonstrated that that the application of geological principles to the planning of opencast workings will lead to the development of larger pits unburdened by problems of drainage and restoration of the land to agriculture.

During the war London alone required well over 250,000 cubic yards of "ballast" for sand bags, concrete defence works and air-raid shelters. The problem of locating sufficient sand and gravel was solved by two geologists in less than a month. Here is a war-time gravel pit familiar to Londoners, the one in Hyde Park between Rotten Row and Prince of Wales Gate. There is a point of incidental interest about the picture; a number of concrete blocks (seen in the foreground) were uncovered in excavating the gravel, and these were indentified as the remains of the foundations of the "Crystal Palace", erected there for the 1851 Exhibition. (*Geological Survey photograph, Crown Copyright Reserved.*)

The strain placed on our shipping by imports coupled with sinkings due to the U-boat campaign made it necessary to develop, as far as possible, all home-sources of minerals which had been considered economically unworkable in the past. Derelict mines for tin, wolfram, lead and zinc were re-investigated by mining geologists on behalf of the Ministry of Supply. In this way much was done to supply industry with these non-ferrous metals. Their systematic survey of the potential resources of the country was made possible by the existence of geological maps containing information about thousands of old mines whose workings had been correlated with the geological structure of the ore-fields. A great economy was thus effected in determining the parts of the areas which were likely to contain workable veins of non-ferrous minerals. In Cornwall, for example, much fruitless searching was avoided amongst the maze of old tin and wolfram mines, while it was possible now to trace new veins; many extensions were successfully made in the mines of the north Pennine area working lead, zinc, barytes, fluorspar and iron ore. Unfortunately, however, it is not yet possible to publish figures to illustrate the results of these geological researches in terms of ore-production, but it can be safely asserted that much shipping space was saved in this way and supplies assured for our war industries. The work of the four principal geologists engaged on this work has provided new information concerning the genesis and disposition of these ore-bodies, with the result that mines can now be planned on more reliable lines than was formerly possible. In this respect mention must be made of the work done by geologists and engineers of the Royal Canadian Army, who introduced novel methods of boring which enabled these veins to be traced with much less expenditure of time and money than was formerly possible. In the laboratories of the Geological Survey and Geological Museum, experiments were carried out on new flotation processes, which gave additional yields of mineral from milled ore extracted from these mines.

Before the war practically no felspar was worked in Great Britain. When foreign supplies were cut off the various users of this mineral appealed to the Geological Survey for information as to where this mineral occurred in workable quantities. Here again reference to the geological maps provided the answer; ample reserves were quickly located. In this way the production of vital war accessories—manufactures such as insulators and all forms of electrical porcelain, for example—was assured without any burden being placed on our shipping. The demand for home sources of mica is part of the same story. Previously all the mica used in this country (mica is essential to our electrical industries and to the manufacture of such things as heat-resisting windows for furnaces) had to be imported. After an intensive search localities were established in the Scottish Highlands where veins of this mineral occurred in workable thicknesses. In this way yet another of our problems of supply was averted. The need for home-sources of sands suitable for glass-making and for use in metallurgical moulding provides yet another example of the many applications to which the vast store of geological information available for this country has been put since the war began. As early as 1920 the sands on the shores of Loch Aline received attention as a possible source for glass sands of even the optical grade. The reward for this

foresight did not come, however, until after all the continental deposits of pure silica sands had fallen into enemy hands. Localities in many other parts of the country were also investigated by geologists and, as a result, it is not improbable that these home-sources will provide serious competition to the former imports of glass sands.

In order to dispel the impression which has been given so far that the work of our small band of highly trained geologists in war-time has been solely concerned with the location and exploitation of raw materials, and particularly of minerals, let us turn to activities which, until recently, have been kept closely guarded secrets.

Geologists attached to the Army, supported by the ever-ready assistance of those on the Geological Survey and in the universities, have been engaged on problems each of which called for detailed knowledge of the geology of this country and of the many widespread theatres of war. For instance, they were faced with urgent questions concerning sites for army camps, the provision of water supplies, and the foundations for defence works and gun sites. Along our many miles of coastline gun-sites had to be selected. In some cases the sites chosen for their strategic value were found to be foundationally unsound owing to the presence of lines of weakness in the underlying rocks such as faults and joints; or to the presence of strata which were incapable of supporting the load, or of withstanding the percussion of gunfire. In such cases alternative sites had to be found; but in many others the strategic value of the position outweighed these geological frailties so that precautions had to be taken to counter the possibilities of landslipping.

Testing Explosives

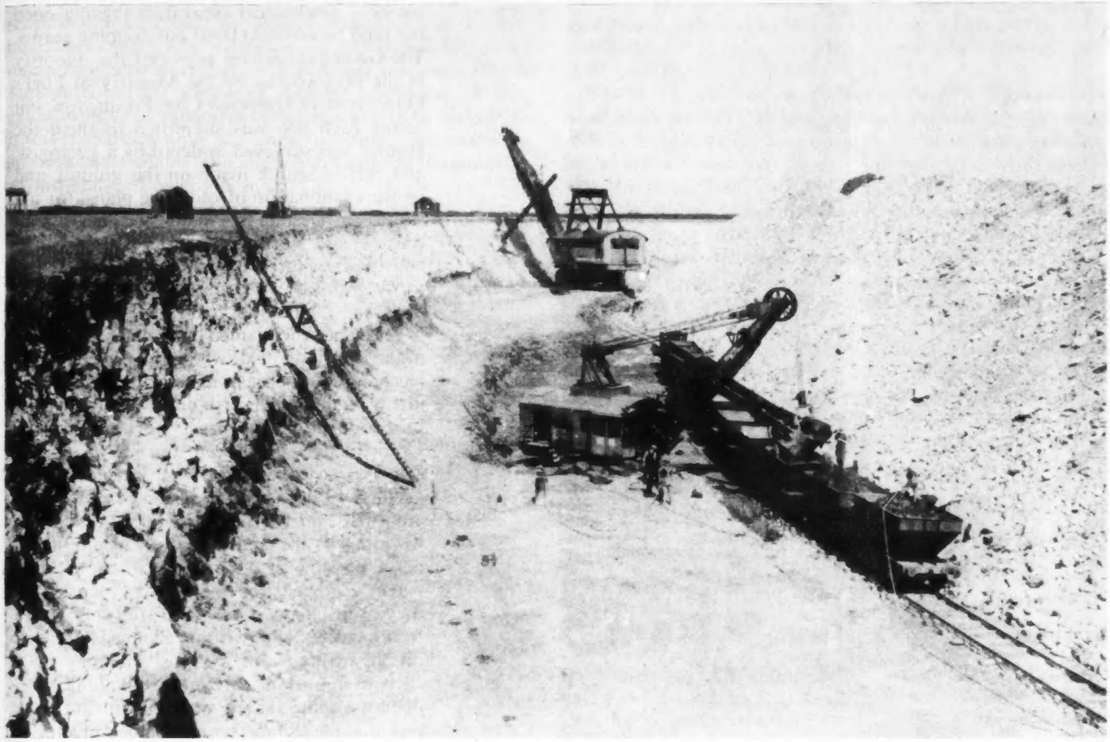
Demands were made for sites wherein various types of explosive could be tested on rocks of different lithology. Geologists were consulted and they located old quarries in rocks of suitable hardness. In some cases limestones loosened by joints and other cracks were desired, in others similar rocks in an unbroken condition were required so that to some extent the shatter-value of our different types of shells and bombs could be ascertained. The results obtained from these tests were carefully recorded, for they provided a basis important to the interpretation of aerial photographs taken after our raids on Germany. Clay lands, for instance, produced many anomalous results owing to the variation in the cushioning effects of this material on bombs of various types. One amusing case was afforded by the investigation of an unexploded bomb dropped by the enemy on the borders of Rutland and Leicestershire. The bomb penetrated fifteen feet of clay and came to rest on a bed of limestone. This bed of limestone is the principal source of underground water in this district, so the excavation soon became half-filled with water. Thus, in addition to obtaining information concerning the passage of the bomb through clay, the hole provided an extra source of water-supply for the neighbouring town of Oakham; as such it will be known for ever more as "Hitler's Well".

In pre-war days the value of water supply has been undoubtedly under-estimated by the majority of people—particularly townsfolk who have grown accustomed to a good domestic supply. Too little did they know of the labours that went to provide their houses with water, and of water's inestimable importance to industry. In the western parts of England and Wales water is obtained mainly from overground reservoirs supplied by springs and pure mountain streams. In the south and eastern counties of England a high proportion of the water is drawn from water-bearing beds of porous limestones, chalk, sands and sandstones by deep wells and boreholes. The location of such underground sources of water is an extremely intricate problem which has always been the concern of geologists, who have constantly advised all the major water-undertakings in this country. The Geological Survey has systematically collected all the evidence available concerning the amount and quality of the water, and the beds from which it is obtained; it has also compiled a good deal of other data obtained from the thousands of boreholes which have been sunk in this country over the past 100 years. Water-levels and their fluctuation due to pumping and to rainfall, and the correlation of all hydrogeological information has been the concern of a small, but well organised unit of the Geological Survey, to which is added the detailed knowledge of every field geologist working in many parts of the country. Their files contain carefully checked and correlated records of over 40,000 wells and boreholes, and from them maps have been prepared showing the distribution of the principal water-bearing beds.

The value of this work was soon impressed on the minds of all concerned with the construction of army camps, aerodromes and new factories. Townsfolk, too, realised the value of water when they were frequently faced with a shortage due to the war-time expansion of the population of the towns to often twice their normal size. Aerodromes requiring as much as 500,000 gallons of water a day presented major problems in areas where local supplies were already over-taxed. In short, had it not been for this systematic work on the hydrogeology of Great Britain carried out before the war, we should have been faced with many serious situations. Instead, these problems were soon solved by this small band of geologists who dealt with hundreds of inquiries on water supply each week at their headquarters in South Kensington, and from distant field-stations where they were engaged on other tasks to some of which reference has been made.

Water for the Army

Wherever our armies operated, water supplies were of primary importance, and the geologists permanently attached to our armies were engaged almost solely on this task of finding water. In North Africa, in Italy, and even in France they were not fortunate enough to have at their disposal an accumulation of hydrogeological data comparable to that available for this country. Despite this, they were able to apply the principles established by our home researches, and a high measure of success was achieved. The provision of a water supply in the Fuka Basin for our troops operating between Tobruk and El Alamein illustrates the importance of this type of work in a military operation. From the Fuka Basin the nearest supply of any quantity of fresh water was 30 miles away at Matruh, which was supplied by the desert pipeline



Blockade brought an expansion of opencast ironstone mining in England. General view of an ironstone pit in Rutland; an electric navvy strips the overburden, in the centre of the photograph a digger is seen loading the ore into trucks, and at the top of the rock face, to the left of the digger, shot holes for blasting the top cover of overburden are being made with a driller. (*Geological Survey photograph, Crown Copyright Reserved*).

carrying purified Nile water from Alexandria—a distance of 110 miles. Along this line there were only two military sources of supply, both of which were small; throughout the remainder of the area the water proved by boreholes was almost invariably saline. At Fuka, however, there were two Bedouin wells which yielded small quantities of fresh water. Geologists and water engineers examined this area in great detail as an extra water supply here would be of great strategic importance to our troops. About 60 boreholes, sunk in as many days, proved that the area contained fresh water above the main water-table which was almost entirely saline. It was also proved that the Bedouin wells were not situated in the place ideally suited to obtain the maximum yield of water without contaminating it with the underlying saline water. These researches located the most advantageous sites, and estimates were made of the quantity of water that could be pumped per day without impairing the continuity of the supply of fresh water. Between September 1941 and March 1942 the Fuka boreholes averaged 50,000 gallons of water a day[1] Then, in the retreat from Tobruk to El Alamein, these important wells were completely demolished, but all records were carefully preserved; the wells afforded no assistance to the enemy. Among the places of high strategic importance selected by Generals Alexander and Montgomery in their plans for the break-through westwards from El Alamein was the Fuka Basin, for it constituted the only supply of water that could be assured for the troops in this forward position. Thus engineers bearing boring-tackle, piping, and pumps followed hard on the heels of the "Desert Rats", and within 48 hours of the area falling into our hands a new borehole had been sunk and a water supply established.

The relief of Malta from its food famine provides yet another example of the importance of water, and the application of hydrogeological principles established in this country. Water was even more scarce than food when "George Cross Island" was being bombed from the air, and blockaded by the U-boats. Sufficient food could be grown on the island if water could be found to irrigate the land; but the water available was adequate only for supplying domestic needs. So in the spring of 1943 the then director of the Geological Survey, Dr. E. B. Bailey, was flown to Malta to investigate the possibilities of obtaining further supplies from underground sources. After making a rapid survey of the porous rocks on the island he was able to provide the sites for boreholes, which yielded the water so desperately needed by the islanders.

As our war-time industries expanded the demand for coal increased enormously. Unfortunately this extra

[1] "The Fuka Basin", article by Major F. W. Shotton in *The Royal Engineers Journal*, 1945, p. 107.

Geologists directed the search for oil in Britain. The picture shows one stage in the process of seismic survey; a shot hole is being drilled, afterwards a charge of dynamite will be inserted in the hole; the echoes reflected back from the sub-strata are recorded at a number of "listening" stations. Correlation of times taken for the explosion wave to be reflected indicate the likely situation of possible oil-bearing strata. (*By courtesy of the Petroleum Information Bureau.*)

quantity of coal could not be obtained readily from our mines, for in the early years of the war pits were denuded of man-power for the army and armament factories. In addition some of the collieries were closed down, and time was needed to rehabilitate them. Thus, some alternative source of coal was needed to supplement existing supplies to power-stations, gas-works, iron- and steel-furnaces and other war industries. Attempts therefore were made, using mechanical excavators and unskilled labour, to win coal from seams occurring near the surface. At first it appeared that this enterprise was doomed to failure, as it was known that the "old men" had mined near surface seams of coal wherever it could be found. However, a close survey of the coalfields, using the geological maps already in existence, showed that there were unworked areas wherein the seams dipped gently into the ground, and were of sufficient thickness to be worked in mechanised opencast pits. The Yorkshire coalfield, for instance, provided many excellent sites and the bulk of the coal won in this country, by this means has come from them. In the same way large pits were located in the Notts-Derby coalfield, and many parts of the exposed coalfields of the Midlands. Soon it was a familiar sight to see huge mechanical excavators digging open the land to win coal from outcropping seams. The Geological Survey provided the majority of the sites worked by the Ministry of Fuel's Directorate of Opencast Coal Production, but before each site was submitted to them the ground was surveyed in detail by a geologist, and careful search made on the ground, and by the examination of old mine plans, for old workings. Despite this many sites, bearing no trace of old workings even after the ground had been explored by boreholes, were found to be riddled with adits and nothing but intervening pillars of coal remained.

The experience gained by geologists working in the ironstone field, where the ore is won by mechanised opencast mining methods in a highly economical fashion, was applied to this problem of opencast working of coal. Unfortunately there were too few geologists available to cover these two great enterprises adequately so that many mistakes were inevitably made in the planning of the open cast workings in the coalfields. In England it was never possible to obtain more than six competent geologists for opencast-coal work, and they were kept more than fully occupied locating sites and writing geological reports on the structure of the site. Geology plays such an important part in the planning of an opencast mine that it was unfortunate there was this lack of personnel in the Directorate of Opencast Coal Production qualified to appreciate its application, and the economies in time and money that result from its application. Nevertheless this tremendous venture succeeded in producing 18½ million tons of coal in this way.

Aerial warfare, as we all know, changed the whole complexion of our home-defences. Factories situated far from the coast and occupied Europe were no longer immune from enemy attack from the air. Thus we, like the Germans, were forced to burrow below ground for safe places in which to work and rest. Enormous underground chambers were excavated to house factories, and to act as storage places for the products of our munition factories. Geologists were employed in the search for old caves and abandoned mine workings, which could be adapted for these purposes. In addition, they acted as consultants when virgin ground was opened up to form chambers for housing factories. It was always of prime importance to know the composition of the strata in the area to be tunnelled, and the extent to which the undertaking would be affected by underground water. In some places the detailed knowledge of the geology of the area provided the means for disposing of the water downwards by means of sump holes into strata which was dry, and capable of absorbing the water that lay above. Advice was also supplied concerning factors connected with roof support, and the bearing strength of the floor of the galleries. In this way engineers were provided with the data necessary for determining the maximum area of roof which could be left unsupported, and the weight of

machinery that could be safely installed. The expert mining geologists, who were engaged on this type of work, were always able to call upon those other members of the Geological Survey possessing detailed knowledge of the area in which the underground factory was to be installed. In this way much time was saved in transferring much of our industrial plant, and valuable stores of munitions, beyond reach of enemy bombs.

This account of war-time geology would be sadly incomplete without some reference to the search for oilfields in this country. This work was started before the war and the first well drilled for oil was put down at Portsdown in Hampshire as early as March 1936. Since them, a small well organised unit of geologists and geophysicists have been engaged on an intensive survey of the likely oil-bearing areas of Great Britain.

In a paper read at the Geological Society on September 6, 1944, the principal pioneer in this field of research described the results which he and his colleagues had achieved in the intervening eight years of endeavour. Dr. G. M. Lees told a big audience of geologists how the work of he, and his colleagues, had "extended through four separate and unrelated geological provinces—the Mesozoic of southern England; the Coal Measures, the Millstone Grit and the Carboniferous Limestone of the areas east and west of the Pennines; the Permian of northern Yorkshire; and the Lower Carboniferous of Scotland."[1] At first their results were unpromising, and appeared to support the gloomy view held by the more conservatively minded geologists in 1937. The boreholes put down at Portsdown, Henfield, Pevensey, Kingsclere, Poxwell, and various others in the coastal area of the Isle of Purbeck were unsuccessful. The seepages of oil known to occur at several places along the south coast failed to provide the deep-seated reservoir hoped for.

"In Scotland a boring at Cousland, near Dalkeith, proved a natural gas production in December 1937, and a well at Aislaby in Eskdale, Yorkshire, struck gas in January, 1939," said Dr. Lees in that lecture. "Some shallow borings in the Coalbrookdale district of Shropshire were unsuccessful, also a deep boring on Gun Hill, near Leek, in Staffordshire. On June 10, 1939, a shallow boring drilled to investigate the source of oil seepages in an area of peat at Formby, Lancashire, struck oil at 125 feet in Keuper Waterstones beneath a cover of recent glacial clay. The initial production was about 3 tons per day."

"While these wells were being drilled, a programme of geophysical work on an extensive scale was being carried out in Nottinghamshire and Lincolnshire to determine structural conditions below the Permian unconformity, in the hope of discovering anticlines with a sufficient cover of Coal Measures over Millstone Grit sands and Carboniferous limestone. At first attention was directed to a large positive gravity anomaly in the region of Nocton, south of Lincoln city, but later an analysis of colliery data and coal exploration borings afforded grounds for expecting an anticlinal axis at Eakring, Nottinghamshire, and this expectation was confirmed by seismic reflection and refraction surveys. A well was located at Eakring as a result, and on June 19, 1939, oil was struck in the Rough Rock sandstone of the Millstone Grit Series. In test the well proved capable of a production of 12 tons per day."

Up to the end of September 1944, 92 exploratory boreholes totalling 188,196 feet have been drilled by the D'Arcy Exploration Company alone. These have resulted in the discovery of five oilfields and two areas of natural gas. In these fields 293 wells with a total footage of 565,360 feet have been drilled for production, of which 244 have been successful. Up to the end of this period the total oil production from these fields was 317,612 tons, (by the end of 1944, the total reached 338,541 tons) constituting a considerable saving in shipping space.

This tremendous field of geological research by geophysical methods for oil fields, followed by deep boreholes drilled to depths of often 6,000 feet at speeds of 500 to 1,000 feet a day, has provided a vast store of information concerning the deep-seated strata in this island. In addition to oilfield discovery, they have revealed extensive areas of coal seams to the east and south-east of Lincoln at depths of about 4,000 feet.

The use of geology during the war has been largely due to the vast store of accessible knowledge of Great Britain housed in the Geological Survey and Museum; and to the application of fundamental principles developed in the past century of geological research to problems throughout the world. In the library of that institution there are over 40,000 volumes dealing with geology at home and abroad; there are 316 maps on the scale of one inch to a mile showing the geology of England and Wales. These form but a part of the library of over 25,000 British and foreign geological maps stored in the museum. With so much information available it has been possible to supply the Services with geological maps and reports concerning such matters as water supplies, roadstones, and material for fortifications several months before an operation. The maps of North Africa, for example, were compiled and supplied to the Services fifteen months in advance. Similarly, as was recently announced by the Deputy Director to the Geological Survey and Museum, a memoir was prepared with geological maps of the area including the Mohne Dam several months before the shattering raid made by Wing-Commander Guy Gibson's force of Lancasters.

The close liaison, which has existed between geologists in the Forces and those in the Geological Survey and the universities, is exemplified by the steady stream of research work directed towards the choice of a suitable beach for landing our forces for the liberation of Europe. Aerial photography provided invaluable information concerning the distribution of the deposits of sand and mud composing these landing places; but up to the last moment the composition of these deposits were unknown as far as their ability to support tanks and guns were concerned. In order to avoid any possible chance of our choice of a landing ground reaching the enemy in time to give him the opportunity to consolidate his defences, a party armed with spades were landed one night towards the close of this long period of preparation. The necessary samples were obtained without them being detected, and these were rushed back to South Kensington where they were analysed and pronounced suitable for landing our mechanised armies on the day scheduled as D-Day.

[1] Abstracts of the Proceedings, Geol. Soc. Lond. No. 1508, 29th Dec. 1944.

What "Consumer Research" Means

On the agenda of the recent meeting of the T.U.C. was a resolution of a rather unusual kind for that body to consider.

It read: "*Congress, recognising the importance of ensuring to the people adequate supplies of domestic and other consumption goods of proved quality and reliability at reasonable prices, instructs the General Council to press the Government to establish a Council for Consumer Research. The functions of this Council shall be:*

(a) to promote factual investigations into the utility, efficiency and cost of advertised consumption goods such as domestic equipment, food and medicaments.

(b) to determine through surveys and by other means the quality, type, and standard of goods required by the consuming public.

The status and methods of financing this Council should be similar to those of the Medical Research Council. It should be required to publish its findings, which should be regarded as privileged comment within the laws of libel.

The resolution was passed unanimously and, moreover, aroused considerable interest in private discussion among delegates.

It is interesting to consider why such a resolution should attract such interest at such a gathering. The idea of consumer research by surveys and the extension of operational research into peace-time consumers' needs may be somewhat novel and less immediately attractive, but there can be little doubt that the individual is immediately receptive to the idea of a mechanism that will protect him as a consumer from being duped or misled by false claims.

The individual purchaser is to day naked in the face of technical advance.

Goods to-day—even consumer goods—are complex products. The housewife using a vacuum cleaner or an electric iron, or listening to a radio cannot be a good judge of their performance. She is probably quite unaware of what a reasonable standard should be; she is influenced in her original choice by advertisements, the salesmanship of a traveller or shop assistant and possibly the comments of friends; she is affected in her estimation of its functioning during her ownership partly by what she was led to expect at the time she made the purchase and largely by use, and pride—as she bought it it must work well.

Her sources of advice tend to be tainted. True, many shops try to maintain a high reputation by recommending only products in which they have confidence, and the well-springs of that confidence may be more or less scientific. But for the most part it is true to say that shops "plug" those goods which offer the largest profit margin. Special bonuses may be offered assistants who succeed in selling some articles that has been deservedly long on the shelf.

The industrialist who buys raw materials and intermediate products or finished accessories sets up his own testing laboratories, which ensure that the goods he buys are up to the standard laid down in the specifications stated in his purchase order. His cooperation with his supplier may extend back even further to the design stage when his technical staff will closely work with the design staff of his suppliers.

What is needed for this individual consumer is unbiased advice, or even purely information, but couched in language that he will understand.

The State already exercises a "police function" on some consumer goods. Foods and drugs are covered by a number of laws, and during the war control has extended, for example, to the meat content of sausages and the fat and bacterial content of milk. Such supervision needs to be extended in the field of food and drugs. It should cover not only harmful articles; the public needs to be guided away from those which are useless. To produce useless articles wastes raw materials, labour and machinery; it involves a social loss that we cannot afford. Such control would be difficult to exercise by legislation; it can probably be achieved by educating the buyer to reject the useless and wasteful articles. The purchaser needs educating so that he can know what he is buying.

In the United States there was set up in 1929 an organisation calling itself Consumer Research Inc. This has since split into two separate organisations but both continue roughly along the lines of this original concern. They are both non profit-making and financed by individuals' subscriptions; they test wares on the market and inform their members in privately circulated bulletins of the results of their tests; they advise as to quality and price. These confidential bulletins may state that the "X" brand of tin-opener leaves shavings of tin in the opened can, or that Firm Y's shirts shrink in all directions or that "Z" make of electric iron is liable to fuse any electricity system on which it is used.

They also publish fairly general guides on the principles to be observed in selecting various types of goods.

The organisations fulfil a very useful function. But their information reaches only those consumers who are sufficiently enlightened as well as sufficiently well endowed to subscribe to the service. The poorer, and perhaps more gullible, sections of the public, benefit not at all. It must be noted that even such limited activity is possible only because America has less stringent laws regarding libel and restraint of trade.

In this country a number of attempts have been made to start such as organisation; they have always foundered on the solemn advice tendered by the legal experts, that they will always land in court because of the common law of Britain which results in a position that one cannot say, even by inference, that Firm A's motor cars are a menace on the road since their braking system is defective even if that statement is true and if heeded will save many lives. As the law stands, the truer such comment the greater offence. If the comment is manifestly absurd, there is likely to be a small bill for damages, but if it is reasonable and true the costs of the case and the damages are almost certain to be ruinous and prohibitive. A straightforward, factual account of a series of tests made on any product giving the results of such tests would almost certainly be libellous.

The sort of organisation that might handle such a task is a government laboratory and physical-testing centre undertaking the testing of food and drugs, medical appliances and patent medicines, household implements and

appliances, and a host of other types of goods. It should operate either under the Board of Trade or as part of a Council, working like, say, the Medical Research Council or Agricultural Research Council. It should examine both old and new products and should be able to initiate any investigation it pleases. Above all, it should be required to publish its findings. These reports might be regarded either as privileged comments (which the Press can then repeat without fear of prosecution) or as fair comment on matters of public interest. In either event the reports should not have to be issued under the menace of a possible action for libel or defamation or what have you.

It should be as much the "done thing" to have a critical appraisal of a new vacuum cleaner or motor car as to have a critic's review of a new book, play or film.

The Council should also have the possibility to initiate proceedings, either in its own right or through the Board of Trade, against manufacturers who issue misleading advertisements or who sell dangerous or harmful goods without clearly stating they are dangerous.

The creation of some such control mechanisms would look after the negative side of consumer protection. The positive side of investigation of the consumer's *real* needs and his belief as to what needs and wants and the operational research aspect of functional analysis is probably much the more important, but it will take longer to develop.

There is no technical reason why the control side should not be set up right now. Perhaps the Government may act on the T.U.C.'s representations.

R. G. FORRESTER.

Plutonium Rivalled U235 as Atomic Explosive

THE British official document on the atomic researches mentioned briefly the discovery of plutonium but gave no indication that it had been prepared in quantity. A great deal of information on this particular point is given in the report which was released to the American press on August 11, but which it was not possible to consult in London until a month later. (This report, prepared by Dr. H. D. Smyth for the U.S. War Department and entitled *A General Account of the Development of Methods of Using Atomic Energy for Military Purposes*, is due for publication by the British Stationery Office sometime in October.)

Self-Sustaining Piles

The immediate purpose of building a self-sustaining chain-reacting pile, to which passing reference is made in the British statements, was to prove that there were conditions under which an atomic chain reaction would occur. But the ultimate objective of the experiment was to produce plutonium (the trans-uranium element of atomic number 94 and atomic weight 239), for it was considered that plutonium might be as valuable as U 235 for making an atomic bomb, while the process of separating plutonium chemically might prove more practicable than the isotopic separation of U 235 and U 238.

The first isotope of plutonium to be discovered was not the 239 isotope but the 238 isotope. Neptunium was isolated from uranium bombarded with deuterons in the Berkeley cyclotron. Later, Pu 238 was prepared in quantities big enough for chemists to begin the study of its chemical behaviour. By the end of 1942, by neutron bombardment of several hundred pounds of uranyl nitrate, the total amount of pure Pu239 salts that had been obtained was of the order of half a gram, sufficient for a great many of its chemical properties to be established by microchemical methods.

The production of plutonium by neutron bombardment follows the lines indicated by the following equations—the prefix numbers for each element being the atomic number, the others the atomic weight.

(1) $_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{92}U^{239} + \gamma$ rays
(*neutron*)

(2) $_{92}U^{239} \rightarrow {}_{93}Np^{239} + {}_{-1}e^{0}$
(*Neptunium*) (*electron*)

(3) $_{93}Np^{239} \rightarrow {}_{94}Pu^{239} + {}_{-1}e^{0} + \gamma$ rays

The half period for U 239 decay in equation (2) is given in the American report as 23 minutes; that for Np 239 as 2·3 days. Plutonium itself decays to U 239 with emission of alpha particles, but so slowly that it is in effect a stable element.

The first self-sustaining pile was built at Chicago—on the floor of a squash court—towards the end of 1942. Between five and six tons of uranium metal, prepared by electrolysing uranium tetrafluoride, were incorporated in it. The pile was built in the shape of an oblate spheroid and constructed of graphite bricks, uranium rods and lumps of pressed uranium oxide, these units being so arrranged that the uranium and uranium oxide made up a cubic lattice embedded in the graphite. (The graphite served as a moderator for delaying the emission of neutrons involved in fission processes).

If the reaction showed signs of becoming too intense, any one of the set of ten cadmium rods that could be slipped into slots left in the pile was capable of bringing the system below the critical condition—the cadmium so acts by absorbing neutrons—and as a precaution one row of uranium bricks was arranged so it could be pushed completely out of the pile if necessary.

This pile was first operated in December, 1942. In the atomic transformations that resulted energy was generated at the rate of about half a watt. The intensity of reaction was then increased up to an energy generation of 200 watts; it was not felt safe to go beyond that, because of the possible effect of dangerous radiations on people in and around the building.

Energy as By-product

The production of a kilogram of plutonium by such a technique would be accompanied by a release of energy amounting to $\frac{1}{2}$-$1\frac{1}{2}$ million kilowatts, so it can be seen that the quantity production of plutonium was thus far from solved at that time.

Large-scale developments followed, however, and with a pile built at the Clinton Engineer Works, a level of over 1800 kilowatts was achieved by June 1944, by which time plutonium was being extracted from the pile residues by the gram. Three other piles were built at the Hanford Engineer Works, presumably with larger outputs than the Clinton pile, though no figures for them are given in the report. All three piles were operating by the summer of 1945.

It has been suggested by several American newspapers that the bomb dropped on Nagasaki contained plutonium; no information on this point is given in Dr. Smyth's account, nor has the suggestion received confirmation—or denial—from any other official source. A memorandum by E. O. Lawrence quoted in the Smyth report says, however, that "if large amounts of element 94 (plutonium) were available it is likely that a chain reaction could be produced. In such a reaction the energy would be released at an explosive rate which might be described as a 'super bomb'."

FIG. 1.—A million-volt X-ray unit, in use examining parts of an army tank. The complete unit, including transformer and tube, is only 6 ft. long by 3 ft. in diameter and weighs 1500 lb.

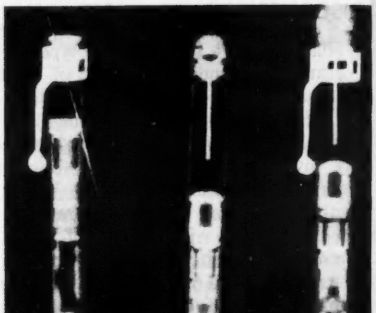


FIG. 2.—Radiograph of three fountain pens. Such pictures show whether the internal components have been properly assembled. (Philips Metalix).

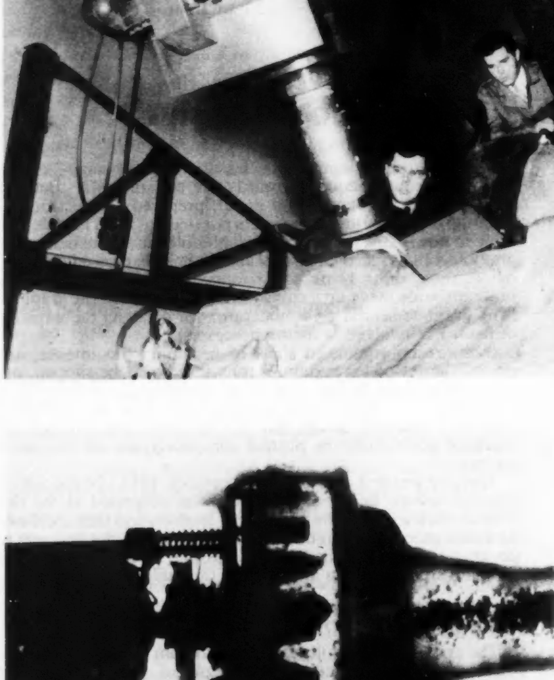


FIG. 3.—High-speed radiograph of a vacuum cleaner in operation, showing the dust travelling from the mouth (right) to the collecting bag (left). Such radiographs can be used to analyse the internal performance of machines.

FIG. 4.—Shows a radiograph of an aluminium alloy casting. The dark patches are caused by cavities in the casting, otherwise impossible to detect without cutting the casting open and thus destroying it. (Victor X-Ray Corporation).

P

IT is no
let alon
which r
graphy
have th
regard
these da
science s
be unab
or allied
engineer
they des
the appl
hardly b
being no
of perm
reference

Under
field whe
he has
which su
"popular
an abstra
turers' le
to provid
obviously
executive
interested
general to
without t

It may
the autho
of boring
grounds
admission
cursory s
neers. It
have som
cares to
value is
bibliograp
obviously
authors c
superficial

The boo
cover mos
graphy in
tends to fo
which hav
from engin
need not b
done by t
separate co
notes betw
useful tech

The first

**Photogra*
Faber & Fa

Photography—An Industrial Tool

G. A. JONES, M.A., A.R.I.C., F.R.P.S.

It is not often that the opportunity occurs of reviewing, let alone writing, a book dealing with a whole field upon which no book has ever before been written. In *Photography in Engineering*,* both the author and the reviewers have this opportunity—or perhaps it would be better to regard it as a responsibility. Certainly it is unusual in these days, when practically every general aspect of applied science seems to be covered by innumerable text-books, to be unable to compare a book with any others in the same or allied fields. Yet the applications of photography to engineering have never before been treated with the respect they deserve, even to the extent of a single book. Indeed, the applications of photography to science as a whole have hardly been covered, ***Photography as a Scientific Implement*** being now so outdated that, though undoubtedly a "classic" of permanent value, it can hardly be considered a useful reference book.

Under these circumstances, Mr. Tupholme had a clear field when he undertook the task and there is no doubt that he has made good use of it. There are several ways in which such a subject could be treated—as a textbook, as a "popular" description of modern scientific wonders or as an abstract of the mass of articles, papers and manufacturers' leaflets, and in other ways. The author has chosen to provide a very readable and profusely illustrated book, obviously designed to appeal equally to the engineering executive interested in new methods, to the photographer interested in new uses for his skill and, above all, to the general technical man wishing to keep abreast of the times without too much hard work.

It may be remembered that Voltaire once said "Woe to the author who wishes always to instruct! The secret of boring is to attempt to say everything." On these grounds Mr. Tupholme should be safe as, on his own admission in the Foreword, the book is intended only as a cursory summary of what the camera is doing for engineers. It is, however, a summary which will undoubtedly have some value and interest for any technical person who cares to read it, owing to the choice of applications. Its value is considerably enhanced by a reasonably good bibliography after each chapter and an index which is obviously intended to be used—a necessity which many authors of technical books unfortunately consider too superficially.

The book is split into eight sections which between them cover most of the more important applications of photography in the engineering industry. In fact, the author tends to forget his title and to put in details of techniques which have far more application to sciences as far removed from engineering as chemistry and biology. However, this need not be considered a fault; considerable damage is often done by the rigid segregation of so-called "subjects" into separate compartments when a more liberal comparison of notes between them would lead to the wider application of useful techniques.

The first chapter deals with the photography of drawings and documents. This may sound uninteresting, or at least unspectacular, but there is a fascination in hearing that documents can be copied, clearly and without the possibility of any error, at the rate of up to five thousand per hour. More than this, the chapter not only deals with the usual "Photostat", "Statfile", "Barcro", "Recordak" and reflex-copying methods, but also gives details of the Vinten record camera, which is not so generally known, and of the recording of machine drawings on metal for the preparation of templates. Photo-template work has grown up entirely during the war, forced on by the need of aircraft firms, particularly in the United States, for the replacement of all laborious hand-work by automatic and rapid methods. Photography has enabled much hand-scribing to be eliminated by copying original drawings on to sensitised metal with an accuracy up to a thousandth of an inch per foot. As the sheets of metal used are often as large as 8 × 4 ft. each (Fig. 1), the giant cameras and enlargers are spectacular as well as being marvels of precision. The various methods of sensitising the metal sheets to light, by transferring a photographic emulsion from paper or by spraying liquid emulsion from a spray gun, are described in some detail. The arrangement of some of the material in this section is open to question and British and American products and processes tend to become slightly confused. It opens with a description of the use of fluorescent copying methods. These are not the most popular in America and are not used, nor likely to be used on any scale, in this country. It would have been better, and more intelligible, if the subject had been introduced by a general description of the methods and if this specialised technique had been merely mentioned at the end. It is a pity, too, that the methods used for photographing and for projecting the line image on to the sensitised metal are only sketchily described and that no mention is made of the Lanston Monotype and similar cameras. Instruments of this type are of huge proportions, usually with the back in a separate dark-room from the front portion, and yet are capable of producing images in which the size of the original drawing is reproduced to one-thousandth of an inch per foot.

One piece of advice given in this chapter is likely to appeal to all—for who has not had to sit through some illustrated lecture at which written matter in the image on the screen was quite illegible? The author lays down clear rules for the preparation of technical slides having sufficient legibility for a hall 80 feet long when using a normal type of lantern. Another technique given in this chapter deserves mention. It is one devised by the Lockheed Aircraft Corporation and enables photographs of complicated assemblies to be printed as negatives on sensitised tracing cloth and finally printed on ordinary blue-print paper to give a positive image of quite tolerable quality—in certain work a varying useful adjunct to the usual line diagram of the blue-print.

At the end of this chapter is a reference to the making of "graticules". These minute scales, used in scientific instruments and gun-sights, are often finer than the thread

***Photography in Engineering*. By C. H. S. Tupholme (London, Faber & Faber, 1945; pp. 276, 73 figures, 188 plates, 42s.).

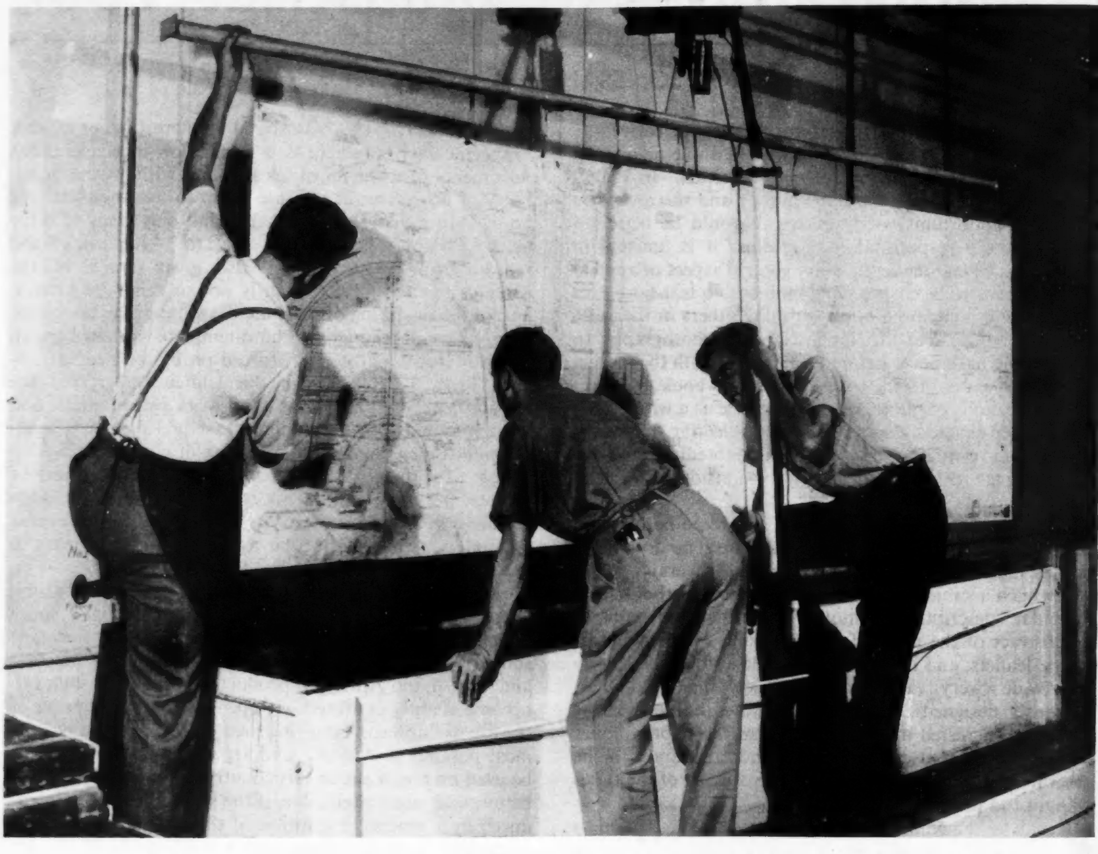


FIG. 5.—Inspecting a photo-template in the dark-room. This is a sheet of metal which has been sensitised photographically on one surface. The line image on it has been enlarged from a small negative made by means of a special copying camera from the original draughtsman's drawing. After fixing, washing and drying, the sheet will be cut up to form individual templates or phototype parts. This method, which can produce templates accurate to one-thousandth of an inch per foot, eliminatess tedious hand-scribing on to metals and enables sheet metal parts to be produced by the "cut out and bend along the dotted lines" principle, thus releasing skilled labour and yet, at the same time, speeding up production very greatly.

of a spider's web and their production has been very greatly simplified by the introduction of sensitive plates capable of recording as many as 25,000 lines to the inch by ordinary photographic means.

In the next chapter, "Photography in the Laboratory", a variety of interesting photographic techniques are mentioned. The author explains how spectrography is used to analyse metals and other substances (Fig. 10), often in a small fraction of the time required for a full chemical analysis. The theory is explained, followed by a description of the modern uses of the ultra-violet spectrograph in light alloy and steel analysis. The accuracy of the method is, of course, of prime importance and the author deals with this in greater detail than with the sensitivity of the method. Spectro-chemical analysis is not as widely used as might be expected at first sight and it is therefore good to see that the author has discussed all the main points, giving a list of the disadvantages as well as of the advantages.

The use of photomicrography for recording the fine structure of metals is now quite commonplace (Fig. 15), though it is not always recognised that the secret of this technique is the proper preparation of the specimens before examination. This is described in full, and, in addition, a number of interesting new techniques are mentioned. Two of these are due to Kayser and are methods of using the standard metallurgical microscope for studying the surface finish of metals. The first consists of the examination of interference fringes formed in monochromatic light between the surface under examination and a microscope cover-glass (Fig. 11). Vertical illumination is used and, as each fringe corresponds to a definite separation between the test surface and the cover-glass, it can be considered as a contour line. The method is primarily of use with finely finished flat or convex reflecting surfaces and gives a striking picture of slight surface irregularities. The second application due to Kayser is a method of obtaining 'optical cuts', i.e. silhouettes of cross-sections of the surface specimens produced without actually sectioning the specimen. This consists essentially of an

arrangement of the metallurgical microscope to allow the photography of the shadow of a straight-edge falling obliquely upon the surface of the specimen. As this can be done at a relatively high magnification, it is possible to obtain a clear picture of the surface irregularities along the line of "optical cut" (Fig. 6).

The author also deals with the electron microscope and the preparation of thin film replicas of metallic surfaces for use with it. The instrument is undoubtedly one of the major scientific inventions of recent years, extending our knowledge of the most minute details of structure which, until recently, were thought to be too small to investigate by any means (Figs. 8, 9). The book shows examples of minute crystals magnified 45,000 times; at this degree of enlargement a human hair would appear about 15 ft. thick or more. The actual use of photography with this instrument is not very satisfactorily covered and, unfortunately, the author deals with sensitive materials for photomicrography immediately after the description of the electron microscope, thus implying that the problems of choosing the correct material are the same for both—an implication which is completely unjustified as materials used to record the impact of an electron beam are quite different, in many cases, from those suitable for photographing the light image of the ordinary microscope.

The question of the use of colour in metallurgical photomicrography is touched upon but the difficulties and uses of colour in this connection are not seriously dealt with. The author is evidently not familiar with R. P. Loveland's paper on "Metallography in Colour", which gives much more complete and up-to-date information, nor does he mention the use of "Dufaycolor"—the only colour film at present available which the photographer can develop himself.

One method used by engineers for determining the stresses in machine parts is by photoelastic analysis. The principle is that a scale model of the part concerned, made in a suitable transparent plastic, is examined in polarised light while the appropriate forces are applied to it. The effect is to produce coloured lines in the model which show the rises and falls of stress in much the same way as a contour map shows the rises and falls in the level of the countryside (Fig. 7) The method given in this book is that employing polarising filters, which was primarily introduced to enable high-speed photography of these patterns to be undertaken. The author does not mention this but it is of some interest because it enables the stresses to be determined in a moving part while the model is actually in motion. By the older method the model had to be held stationary while a time-exposure was made, but with the apparatus mentioned exposures as short as one-thirty-thousandth of a second can be given to catch the stresses in any particular position of a moving part as it moves at high speed.

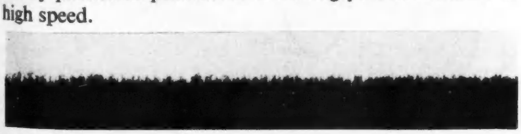


FIG. 6.—An "optical cut" of a ground surface (magnification × 170). This is a magnified image of the shadow of a straight-edge falling on the surface, which effectively produces a silhouette of the cross-section at the point concerned, but without actually having to cut the specimen.

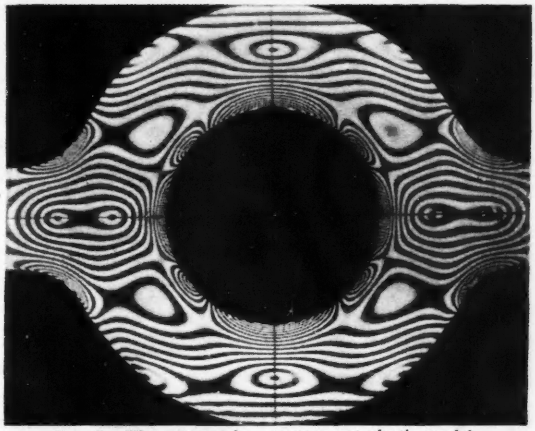
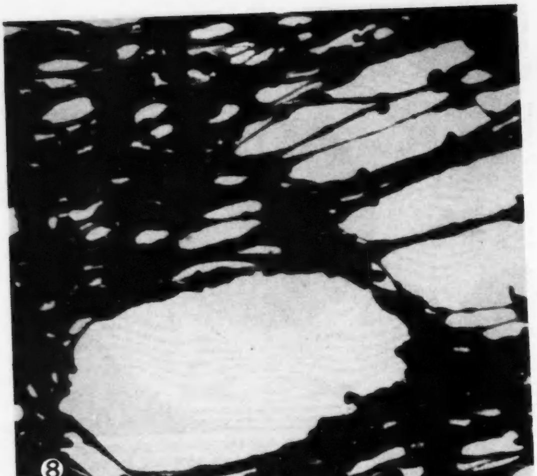


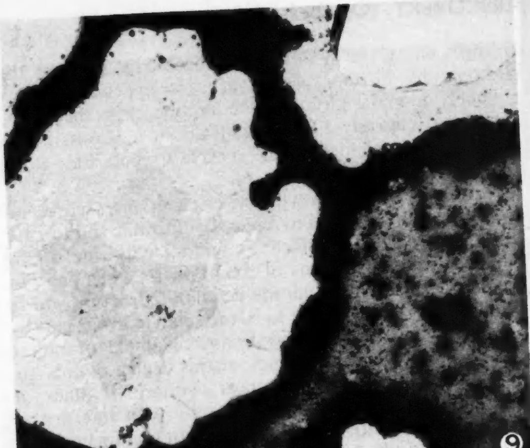
FIG. 7.—The patterns in a transparent plastic model of a double-ended eye-bar, held in tension, as seen under polarised light. These indicate the stresses in the bar—where the lines are close together, there is a high stress gradient and where they are far apart the gradient is low. This method, known as photoelastic analysis, is used by engineers to determine stresses when to do so by mathematics would be difficult or impossible. (*British Plastics.*)

The next chapter is devoted to modern methods of high-speed photography by which exposures as short as that mentioned in the last paragraph are made possible. This is, perhaps, one of the most interesting and spectacular applications of photography, and one which has been used considerably during the war. It embraces the taking of photographs of moving objects as fast as rifle bullets by means of exposures as short as one-millionth of a second (Fig. 13), and also the analysis of motion with ultra-slow-motion cine cameras capable of producing films showing movements slowed down to less than one thousandth of their actual speed. It is, perhaps, a little unfortunate that the author classes the stroboscope as a piece of photographic equipment. It is, of course, mainly used for visual work, the principle being that any cyclic motion can be made to appear stationary by examining it by means of a flashing light source which flashes regularly once every revolution; if the flashes are more frequent than this the cycle appears to move backwards slowly while if they are less frequent it appears to move forward. Such a light-course rarely provides sufficient light for high-speed photography and, in any case, does not provide a true "slow-motion" record of the movement but only an illusion based on an integration of the actual movements; any small irregular movements occurring at random will not be apparent. On the other hand, true slow-motion photography will follow these unless they are of shorter duration than the time between one picture on the film and the next.

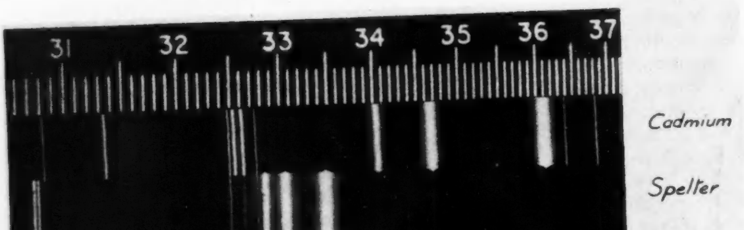
On the other hand, the standard apparatus for high-speed photography, is fully described, including the "Strobolux" and the "Kodatron" lamps, capable of giving a flash of immense intensity lasting only about one thirty-thousandth of a second and the "Vinten" and "Eastman" high-speed cine cameras which can take up to three thousand or more pictures per second. The interesting applications given include the analysis of lightning strokes, the use of the Schlieren technique for photographing vapours and hot air (Fig. 14) and the analysis of the movements of train wheels on rails.



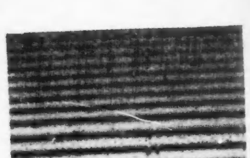
8



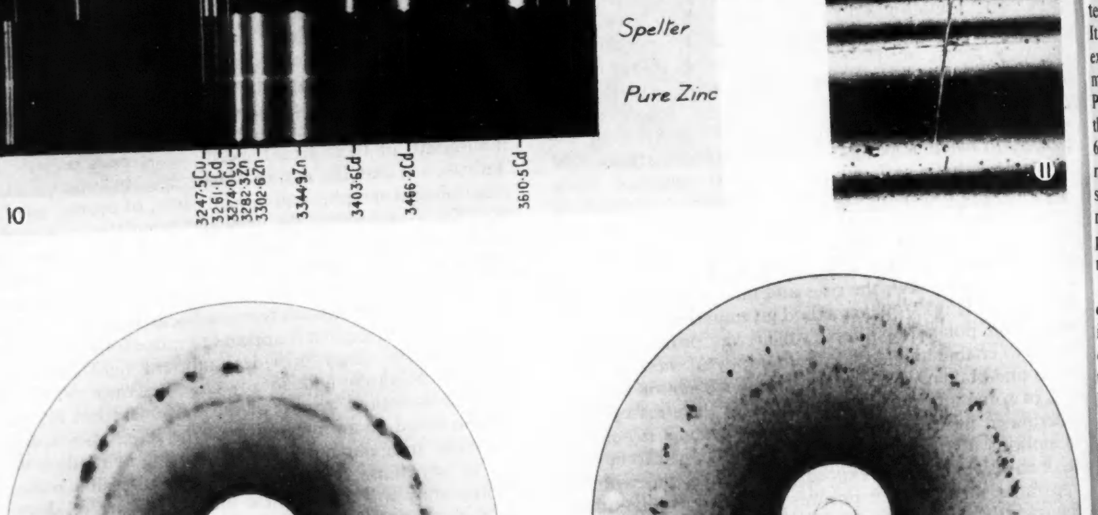
9



10



11



(a)

12

(b)

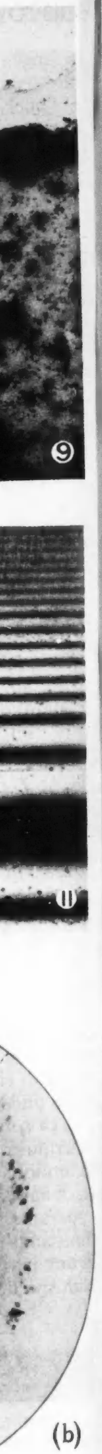
While this
to which the
give a summ
wishing to m
a pity that t
ones chosen
able interest
of drum an
high-speed
electric spar
work on th
Fraser, Oliv
at all. It wo
details of the
for recordin

X-Ray Ph

Chapters
uses of X-ra
the book sh
graphic ma
more imme
ability to te
to cut the
value, whil
study of cr
as importa
with non-
giving deta
techniques
It also inc
examining
method of
Probably t
the million
6 inches of
radiograph
sec. is also
radium as
penetrating
needed.

Chapter
crystal ar
introduced
of modern
the more
how the d
structure
patterns t
form of L
A selectio
trated and
list of the

FIGS. 8 an
chloride (m
mately).
FIG. 10.—
from 3050
FIG. 11.—
glass surfac
the fringes
FIG. 12.—
aluminium
general on



While this chapter contains a number of minor points to which the expert on the subject might object, it does give a summary of real use to the engineer or scientist wishing to make use of high-speed photography and it is a pity that there were not more illustrations, though the ones chosen are mainly of very high quality and considerable interest. Although a description is given of the use of drum and mirror cameras for special types of ultra-high-speed recording, it is surprising that the use of the electric spark as an illuminant in ballistics and the classic work on the explosions of gases carried out by R. P. Fraser, Oliver C. de C. Ellis and others are not mentioned at all. It would also have been interesting to have included details of the "strip-camera" developed in the United States for recording the flight of rockets and other projectiles.

X-Ray Photography

Chapters 4, 5, and 6 deal with various aspects of the uses of X-rays. It is probably appropriate that so much of the book should be devoted to a property of the photographic material which is far more widely utilised and of more immediate value in engineering than any other. The ability to test metal parts for internal flaws without having to cut them apart (Fig. 4) is obviously of inestimable value, while the increasing use of X-ray diffraction in the study of crystal structure is likely to become practically as important before long. Chapter 4 deals exclusively with non-destructive testing by radiography (Fig. 2), giving details of the equipment used in industry and the techniques used for steel, light alloy and weld radiography. It also includes mention of the use of "soft" X-rays for examining softer materials such as cloth and gives a method of making stereoscopic radiographs of textiles. Probably the most interesting portion is that dealing with the million-volt X-ray unit capable of penetrating up to 6 inches of steel (Fig. 1), though an example of high-speed radiography taken with an X-ray flash lasting 1/500,000 sec. is also highly intriguing (Fig. 3), as also is the use of radium as a source of X-rays, for work where very high penetrating power and a small source of the rays are needed.

Chapter 5 deals with X-ray and electron diffraction in crystal analysis and with micro-radiography. This is introduced very well and a very clear description is given of modern uses of such techniques for the examination of the more minute aspects of materials. The author shows how the diffraction of X-ray beams by the regular atomic structure of crystalline substances can be used to produce patterns typical of the substances concerned, either in the form of Laue, rotation or powder photographs (Fig. 12). A selection of types of apparatus for this work is illustrated and dealt with and a very long and extremely useful list of the uses of X-ray diffraction in industry is given.

Following a description of an adaptation of the electron microscope to electron diffraction for similar purposes, microradiography is mentioned. Where photomicrography will show up the minute structure of the surface of materials microradiography (or, to give its more generally accepted name, X-ray micrography) will show the minute internal structure—though not as minute as the atomic structure revealed by X-ray diffraction. The principle is simply to make a radiograph on a photographic material capable of producing an image which can be greatly magnified. This negative is then enlarged as far as is necessary or possible, thus revealing very small defects and the gross structure of the materials.

A special chapter is devoted to the processing and storing of X-ray materials. The utility of this appears to be doubtful, as the handling of other photographic material is entirely omitted and there seems to be no particular reason for stressing this aspect of radiography. However, it is a short chapter and is followed by two, equally short but of greater interest. These deal with infra-red photography and instructional motion pictures. The former includes an interesting description of the recording of the nuclei of rust on tin-plate by infra-red photography; the rust is penetrated by these rays and the pores in the plate, where the rusting started, are thus clearly recorded. Mention is also made of the recording of temperature distribution on hot surfaces by means of infra-red photographs, though unfortunately no illustrations are shown. As the plate is sensitive to these infra-red heat rays, the surface is shown in the photograph as if it were white-hot, whereas to the eye it appears cold.

The last chapter deals with instructional motion pictures. It is, of course, quite impossible to cover this very wide subject in the space of one chapter. Actually the author, probably wisely, merely outlines the uses of cinematography for instruction in industry, in the space of a few pages. It would not be difficult to write a separate book, as long as the whole of *Photography in Engineering*, dealing with cinematography in engineering; perhaps this short final chapter is intended as a forerunner to such a book. The author contents himself, here, with reference to the value of motion pictures for showing employees new techniques and mentions the use of the film for advertising and demonstration purposes. As an example of a training film *The Inside of Arc Welding* is cited and a number of "stills" and sketches from it are shown.

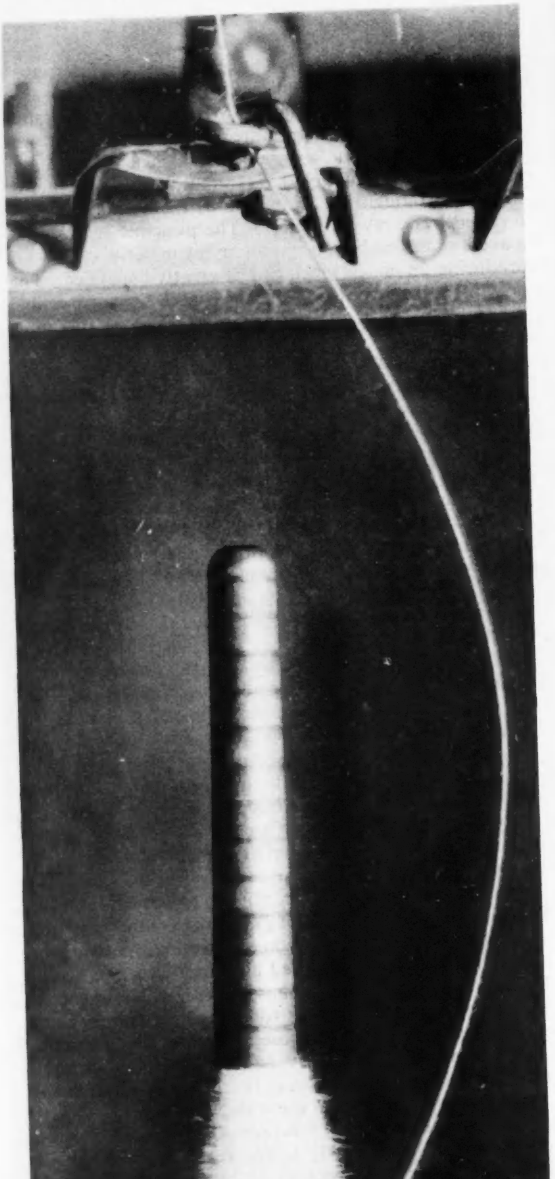
There is no doubt that *Photography in Engineering* makes good reading, particularly to the technical man who is interested in the many ways in which photography can be used in industry. It would have made still better reading if it had been compiled in a somewhat different fashion; the author varies considerably in his approach to different subjects and tends to be both uncritical and unduly long-winded in parts, while omitting some photographic

FIGS. 8 and 9.—Photomicrographs taken with the electron microscope. Fig. 8 shows partially polymerised vinyl chloride (magnification about 16,000 times). Fig. 9 shows rubber cement containing fine grain carbon (× 6500 approximately).

FIG. 10.—A small portion of comparison spectra of cadmium, spelter and pure zinc. The scale is of Angstrom units, from 3050 to 3720 (Adam Hilger Ltd.).

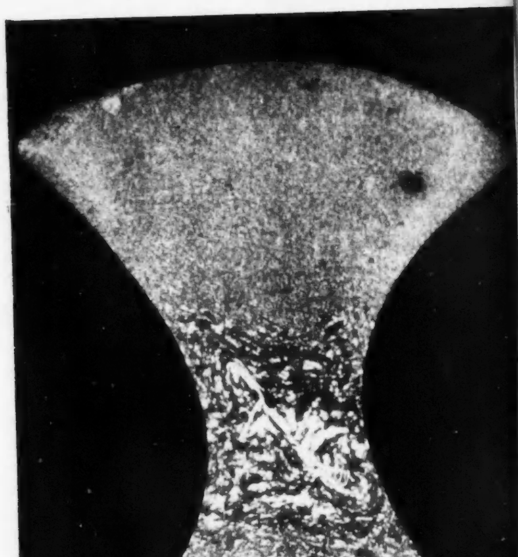
FIG. 11.—Interference fringes produced in monochromatic light between a surface under examination and a plane glass surface. It will be seen that the fine scratch on the surface tested stands out clearly owing to the displacement of the fringes; the degree of displacement is a measure of the depth of the scratch (magnification, about 200 times).

FIG. 12.—Diffraction patterns obtained when a beam of X-rays impinges on (*a*) pure aluminium and (*b*) anodised aluminium. The difference between the patterns provides a method for instant differentiation and the method is a general one applicable to very many other substances.



13

14



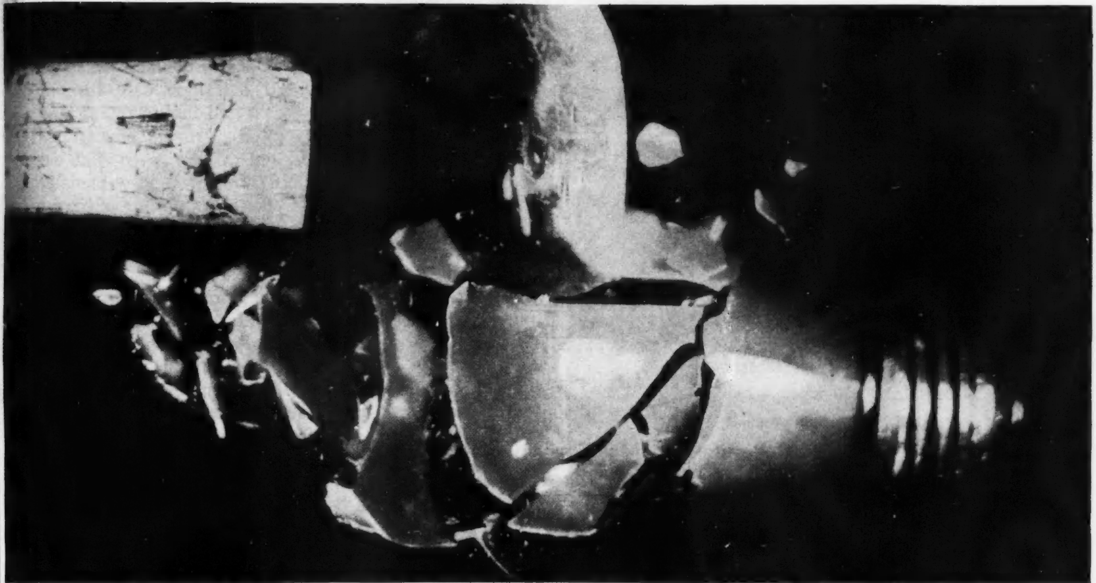
15

techniques
It would l
the variou
under pra
document
mentioned
costs, nor
work comp
names mar
to the mos

A furthe
of the ma
point in gi
X-ray ma
dealt with
application
use in engi
and specim
so on—is r
given a bri
photograp
value to-da
are often m
liquid and
the cracks
tographica
oils and ot

In any b

FIG. 13.—A
tions per mi
Germeshaus
FIG. 14.—A
at the top.
air currents.
FIG. 15.—A
centre, wher




14


15

FIG. 16.—An electric light bulb is being smashed with a hammer. The camera has caught the flying glass before it has had time to fall. (General Radio Company.)

techniques entirely and perhaps over-emphasising others. It would have been particularly interesting to hear how the various techniques and makes of apparatus compare under practical conditions. For instance, in discussing document copying, a number of different systems are mentioned but no comparisons are made of the running costs, nor are their merits for different types of industrial work compared. Similarly, the section of photo-templates names many processes but does not give much guidance as to the most suitable to choose for various types of work.

A further criticism which can be levelled is the selection of the material. As mentioned above, there seems little point in giving a whole chapter to processing and storing X-ray material when other photographic processes are dealt with only extremely sketchily. In particular, the application of photography which is probably of widest use in engineering—the straightforward recording of plant and specimens for report illustrations, sales brochures and so on—is not mentioned at all. Infra-red photography is given a brief chapter to itself but ultra-violet fluorescence photography is not mentioned. The latter is of as much value to-day as the former; cracks in forgings and castings are often made apparent by bathing the part in a fluorescent liquid and examining it under ultra-violet radiation, when the cracks stand out clearly; this can be easily recorded photographically. Similarly, the contamination of surfaces by oils and other fluorescent substances can also be recorded.

In any book which is the first on its subject there must be omissions and errors. It would be tedious to enumerate these here, though the book would have been made more complete and more interesting by the inclusion at least of such standard techniques as the photographing of dials (particularly of aircraft dials during flight), aerial survey for purposes of civil engineering, stereo-photography for recording complicated assemblies of machine parts and electrical wiring, the photographic preparation of name-plates and dials, furnace photography, time-lapse photography for speeding up motions too slow to appreciate and the use of photography for recording and evaluating street-lighting and other problems of illuminating engineering.

In some places details of photographic technique are given, but on the whole this is a book to be read for general interest rather than as a text-book. The impression given is that the author is interested in what can be done, rather than in exactly how to do it. The book would have been far more powerful if it had been less impartial and had discussed its subject from the point of view of the engineering executive who wanted to know how to make use of photography. As it is, the author has broken new ground and produced a very readable summary of most of the major photographic techniques used in industry to-day. It is a book which can hardly fail to interest any technical man, though it will not also fulfil his probable next request—for a text-book to instruct him in how to use photography in engineering.

FIG. 13.—An ultra-high-speed photograph of cotton yarn "ballooning" from a spindle turning at 10,400 revolutions per minute. From such records the performance of machines working at high speeds can be analysed. (Edgerton, Germeshausen and Grier).

FIG. 14.—A shadow photograph of convection currents rising from an experimental light fitting having a baffle plate at the top. A method known as "Schlieren" photography enables such shadow records to be made of vapours or hot air currents. The effect depends upon the variation in the refractive index of the medium and is extremely sensitive.

FIG. 15.—A photomicrograph of a cross-section of a high-speed steel drill. The difference in composition near the centre, where carbide segregation has taken place, is very clear. (Ford Motor Co.).

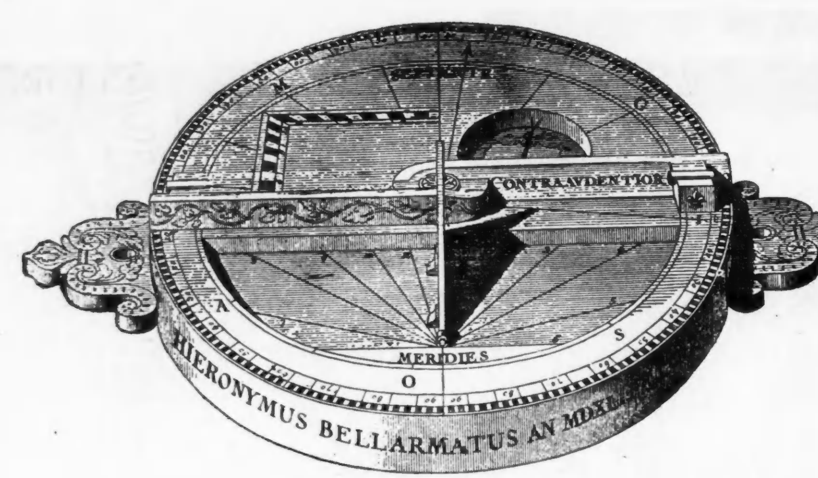


FIG. 1.—An ivory sundial constructed in 1541 by Hieronymus Bellarmatus; showing the first known value of the magnetic declination at Paris (7° E).

The Earth's Magnetism

Professor S. CHAPMAN, F.R.S.

MAGNETIC SCIENCE began with the discovery that certain stones, later called lodestones, attract iron, and by stroking can impart their own power to it. This was known to the ancient Greeks; so also was the quite different *electric* attraction exerted on light objects, such as bits of thread or feathers, by amber when rubbed.

Ages later, perhaps about the time of the Norman conquest, some unknown great benefactor of mankind found a new property of the lodestone or magnetised iron. When free to turn, for example, if pivoted, or on a floating support, it sets itself nearly north and south.

Thus the mariners and the land travellers gained the magnetic compass, which Kelvin's genius greatly improved even after centuries of use. It has won new importance in our day in air navigation.

In time the compass led to a new discovery in pure science. It distinguishes between the two ends or *poles* of a lodestone or magnet; one seeks the north, the other the south. It was found that magnetic *attraction* occurs between *unlike* poles, whereas any pole *repels* another of like kind. This repulsion had escaped the notice of the Greek scientists. The simple qualitative statement "like poles repel, unlike pole attract" is the basic law of magnetic science. Our first record of it was written by a French soldier-scientist, Peter the Pilgrim, in 1269, and first printed in 1558. (Fig. 2).

Peter believed the compass pointed truly north, and so did most people for two or three centuries after him Roger Bacon, in Peter's time, thought otherwise. But at that date this might have been supposed to be due to an imperfect compass needle or pivot, or to the compass case not being truly non-magnetic, or, again, to an error in the measurement of true north. Only gradually did it come to be recognised and established that the compass in general deviates or *declines* from true north.

The compass error, or *declination*, forced itself on the notice of the Nuremberg makers of sun dials, about 1400 or 1450; they probably found that a dial set by aid of the compass indicated noon at a time when the sun was not at its highest. They traced the error to the compass, and measured the declination by finding the true north from the sun or stars. The best makers indicated this error by a mark on their dials, so that the purchaser could set up the dial correctly though using a compass.

Some small dials so marked were made for land travellers to tell the time, and had a compass in the base, for setting. Such marks are among our earliest definite man-made records of the magnetic declination. (Fig. 1).

By about 1490 some map makers of Nuremberg had copied the dial makers in printing an arrow, as on modern maps, to indicate the compass error.

In 1525 a Seville apothecary named Guillen added a central vertical rod to his compass case, so that by its shadow the magnetic bearing of the sun could be measured. He showed how the true north, and the compass declination, could be found by taking magnetic bearings of the sun before and after noon, at equal altitudes as measured by an astrolabe.

This instrument, given to the Portuguese Infante, was tried out by his friend and former fellow-student de Castro, navigator, commander and later Indian viceroy (Fig. 3). In the course of a voyage to India and the Red Sea (1538-1541), he made 43 measures of the magnetic declination. Though the journey was for trade, it also constituted the first ocean magnetic survey. Unfortunately these measures were published only in the nineteenth century, after rediscovery in the Portuguese archives.

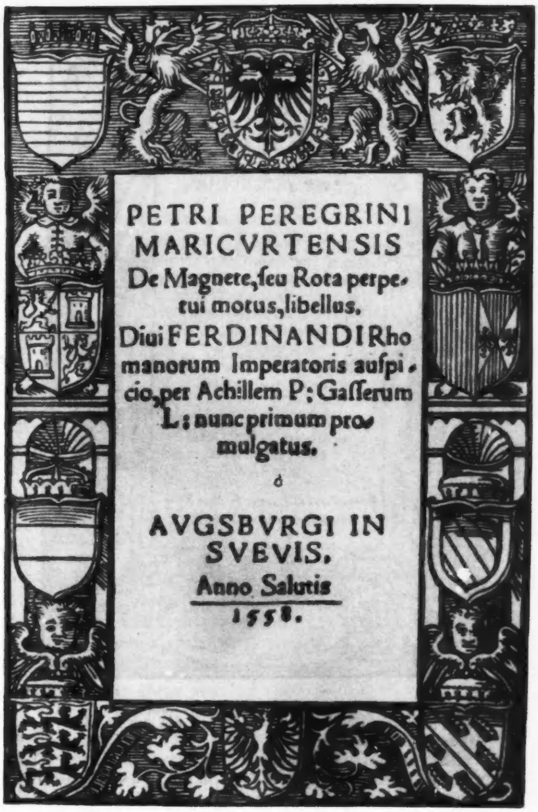
By 1550 it was common knowledge among navigators that the compass departs from the true north, by different

angles in different places; but many landsmen remained ignorant of these facts, including some map makers, as Mercator complained in 1546.

Mercator also contested the common idea that the compass is controlled by an influence in the heavens. It cannot, he said, be attracted to any star, because they all revolve daily round the celestial pole, whereas the compass points steadily at an angle to this pole. Hence there must by a fixed point of attraction on the earth. Thus, five centuries after the discovery of the compass, Mercator realised, if only dimly, that this discovery was the beginning of geomagnetism, the science of the magnetism of the earth.

Mercator even attempted to find this terrestrial point of attraction—what we should now call the magnetic pole. He drew great circles on a globe, through Walcheren and Danzig, inclined to the geographical meridians by the known magnetic declinations at these places. His position of the intersection, north-west of Bering Strait, was over 1,000 miles beyond the actual north magnetic pole.

In 1581 appeared the first printed work dealing solely with geomagnetism—*The Newe Attractive*, by Robert Norman, a London dockland nautical instrument maker. He announced the fundamental discovery of the magnetic *dip*: that a needle free to turn in any direction, and perfectly balanced before being magnetised, afterwards dips steeply downwards from the compass direction.



PETRI PEREGRINI
MARICVRTENSIS
De Magnete, seu Rota perpe-
tui motus, libellus.
Diui FERDINANDI Rho
manorum Imperatoris auspi-
cio, per Achillem P. Gasserum
L. nunc primum pro-
mulgatus.

AVGSBVRGI IN
SVEVIS.
Anno Salutis
1558.

FIG. 2.—The title page of the first printed version of the Letter by Peter the Pilgrim (A.D. 1269) on the magnet; it was written from the camp at Lucera, in Italy, then under French siege, to his neighbour at home in Picardy.

Hence he argued that the needle is controlled by the earth, but by a point within the earth, not in the far north. He also showed that the needle is not bodily attracted to this point, but only turns to it. (Figs. 4, 5).

London at that time housed another magnetic philosopher, the noted Dr. William Gilbert of Colchester, afterwards Queen Elizabeth's physician. His leisure was devoted to experiments of magnetism, and also on frictional electricity, and he searched out magnetic lore in all the ancient, medieval and modern books. At last in 1600 he published a large treatise in Latin, *De Magnete*, giving the fruits of his many years' reading and experiments. He winnowed the much chaff from the little grain in the earlier writings, and described a multitude of his own discoveries. (Figs. 6-10).

But the most memorable contribution of this immortal book is to geomagnetism. It is summed up in the sentence, *magnus magnes ipse est globus terrestris*—the earth globe itself is a great magnet. He based this statement on experiments in which he set tiny pivoted magnetic needles at different points on a lodestone ground to the spherical form. They dipped obliquely (as Norman's dip needle did towards the earth) except at the two poles of the lodestone,

FIG. 3—De Castro.

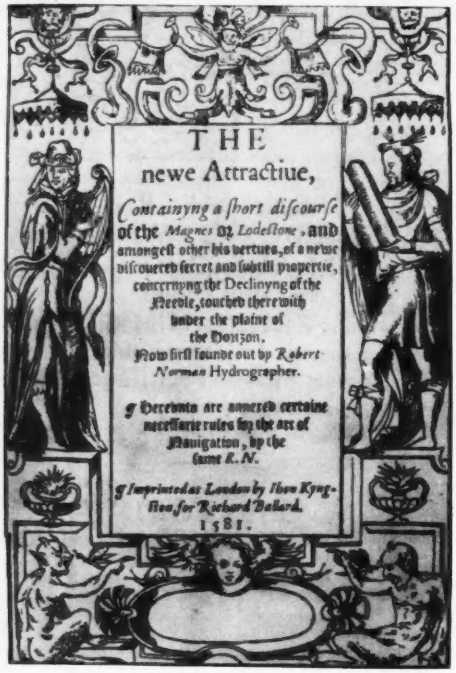

THE
newe Attractiue,
Containyng a short discourse of the Magnes or Lodestone, and amongest other his vertues, of a newe discouered secret and subtill propertie, concernyng the Declinyng of the Needle, touched therewith under the plaine of the Horizon.
Now first founde out by Robert Norman Hydrographer.
¶ Hereunto are annexed certaine necessarie rules for the art of Nauigation, by the same R.N.
¶ Imprinted at London by Iohn Kyngston for Richard Ballard.
1581.

FIG. 4.—Title page of Robert Norman's book in which he announced and discussed his discovery of the magnetic dip.

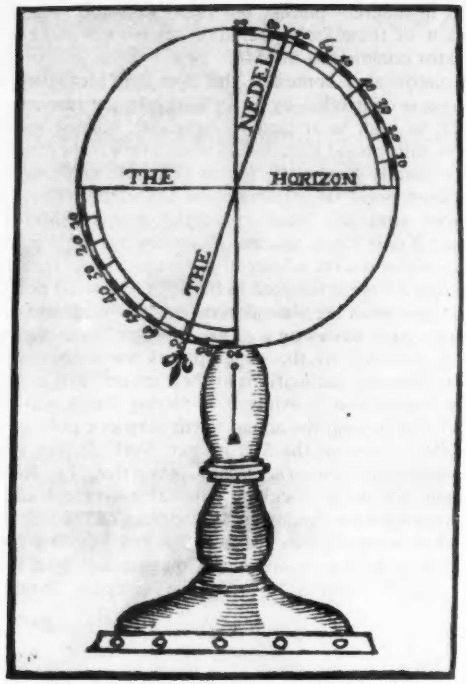


FIG. 5.—Robert Norman's diagram of his freely balanced compass needle, showing the magnetic dip at London in 1576.

where they stood perpendicular, and on the circle midway between the two poles—the magnetic equator of the lodestone, as Gilbert called it—where they lay parallel to the stone, pointing towards its pole.

His mind made the long leap from his globular lodestone and his tiny needles to the great earth itself. This, a giant magnet, controls our compasses and dip needles in like manner, with an influence proceeding, as he showed, from its whole magnetic body, not only from the poles or, as Norman thought, from an internal "point respective".

Gilbert drew lines on his spherical lodestone, showing at each point the direction taken by his tiny needles; these lines, which he called magnetic meridians, passed directly from one pole to the other. He knew that the compass direction on the earth was not so regularly distributed, and wrongly ascribed this, over the oceans, to the landward magnetic attraction of the continents. Hence he asserted that except for great convulsions like the fabled submergence of Atlantis, the magnetic direction must everywhere remain constant.

This, indeed, seems never to have been doubted. But in 1635 it was proved untrue. Gellibrand, a professor of Gresham's College, London, measured the declination there in 1634 as 4°.1E; he compared this with earlier observations, 6°.0E in 1622 and 11°.3E in 1580, and recognised that the differences were too great to be errors of measurement, and indicated a long-continuing natural change—the so-called secular magnetic variation. These conclusions he published in a book called *A Discourse Mathematical on the Variation of the Magneticall Needle*.

This adds a new interest to geomagnetic observation, and imposes new duties. Every measurement ought to be dated, and only serves for a time. For navigation and for science the measurements must at intervals be repeated, to follow the changes.

The next great benefactor to geomagnetic science was Edmund Halley—Halley of the comet—friend, disciple and helper of Newton, Oxford professor and second Astronomer Royal—a man outstandingly able, versatile, and ardent in the pursuit and practical application of science. The earth's magnetism was his lifelong interest, next to astronomy. (Figs. 11, 12).

At intervals from boyhood to old age he measured the compass declination at London, and his treasured needle was taken and used on his many astronomical and other journeys, to St. Helena, Danzig, Paris, Italy, and elsewhere. He also collected observations made by others, and showed that Gilbert was wrong in asserting that at sea near the land the needle always deviated landward from its general direction.

To explain the secular variation he suggested that the earth is not solid but consists of a central core surrounded by one or more spherical shells, magnetised in different directions and rotating at slightly different rates, so that the surface field slowly varies. The theory, he agreed, seemed fantastic but, as he said, not more so than Saturn's rings, then lately discovered. Since Halley's day the study of earthquake waves has definitely disproved his theory, but he cherished it to the end.

It had the great good effect of spurring him on, for

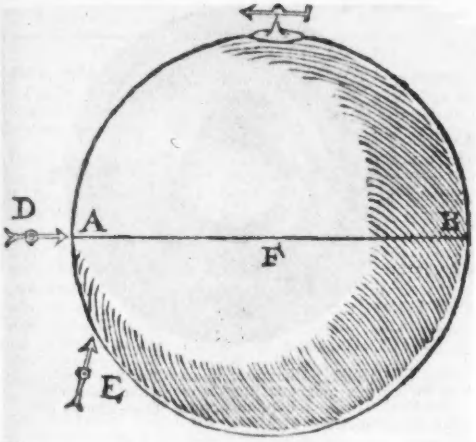


FIG. 6.—A diagram from William Gilbert's Latin treatise *De Magnete*; showing small pivoted magnetic needles placed at various points of a spherical lodestone.

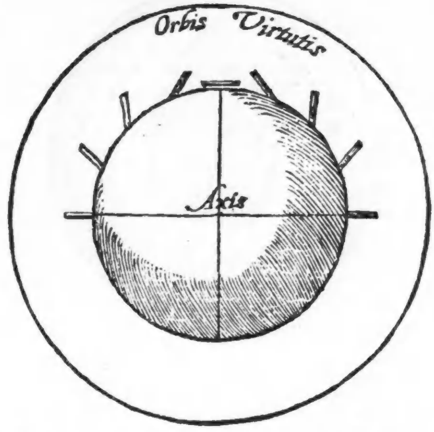
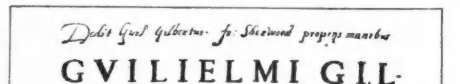


FIG. 7.—Gilbert's diagram showing the magnetic dip at various "latitudes" on a spherical lodestone.

scientific as well as practical reasons, to make a magnetic survey of the North and South Atlantic oceans. He induced the Admiralty to provide a ship for the purpose and, marvellous to relate, to appoint him, a landsman, its captain. His second in command, a regular officer, found this so irksome that he mutinied. Halley put him under arrest and himself navigated the ship home, to set forth again with a more amenable mate.

Soon after his return in 1700 he published a new type of magnetic chart of the Atlantic, to make his two years' observations available to seamen. He drew lines on his map connecting points at which the compass had the same direction, so many degrees east or west of north. By interpolation between these *isogonic* lines the declination at any point can readily be found. In 1702 he published a magnetic chart giving the isogonic lines also over the Indian and West Pacific oceans, using observations made by mariners in these seas.

These charts had a wonderful success and, even after his death in 1742, they were copied and republished. At last, as he had foretold, the secular variation made them obsolete except as scientific records.



Dedit Guil. Gilbertus. Jo: Sherwood propriis manibus

GVILIELMI GIL-
BERTI COLCESTREN-
SIS, MEDICI LONDI-
NENSIS,

DE MAGNETE, MAGNETI-
CISQVE CORPORIBVS, ET DE MAG-
no magnete tellure; Phyſiologia noua,
plurimis & argumentis, & expe-
rimentis demonſtrata.

LONDINI
EXCVDEBAT PETRVS SHORT ANNO
MDC.

FIG. 8.—Title page of Gilbert's *De Magnete*.

FIG. 9.—Dr. William Gilbert.

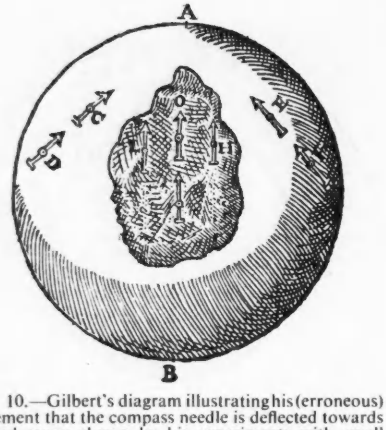


FIG. 10.—Gilbert's diagram illustrating his (erroneous) statement that the compass needle is deflected towards a land mass; shown by his experiments with small needles placed on a spherical lodestone with an irregular projecting part.

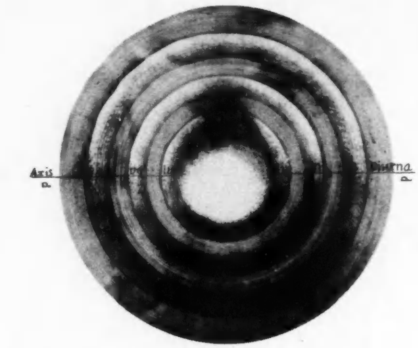


FIG. 12.—Halley's diagram illustrating his theory of the earth's magnetic poles and secular magnetic variation. (From the Philosophical Transactions of the Royal Society, 1692).

Halley's charts contained a serious geographical error: the southern part of America was placed 10° too far west. At that date the problem of measuring the longitude at sea had not been solved by the invention of reliable chronometers, and ocean currents could badly falsify the longitude determined from the log. In Halley's time, and even into the nineteenth century (1804), some hope was felt that the magnetic declination might help to determine the longitude; as he saw and stated, this would be so only at places where the declination varies along the east-west direction.

Others hoped that the magnetic dip would help mariners to find their latitude when clouds prevented astronomical observations. This idea is sound if the magnetic dip has first been surveyed and charted, but its practical value was reduced because of the difficulty of measuring the dip accurately at sea. The error would be a few degrees of dip, whereas on the old wooden ships the declination could, with care, be measured to a degree. On modern steel ships the difficulty is much greater.

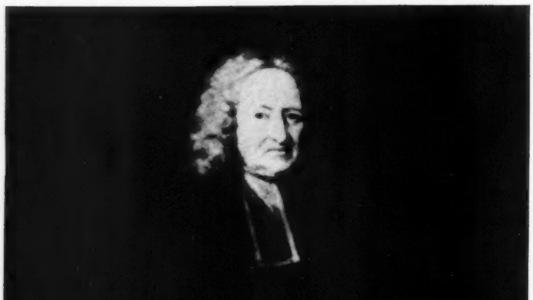


FIG. 11.—Edmund Halley in his old age, holding in his hand a copy of his diagram of the earth and its interior structure as conceived by him to explain the earth's secular magnetic variation.

Measurement of the dip was sadly neglected for two centuries after Norman's discovery of it. Neither Gilbert, nor Gellibrand, nor even Halley, seem to have left us any dip observations. The first world chart of the dip, shown by isoclinic lines of equal dip, was published in 1768 at Stockholm. These lines encircle the globe rather smoothly, mostly at no great angle to the circles of geographical latitude. They enclose the two magnetic poles, where the needle stands vertical, and all indication of compass direction ceases. Near these poles the isoclinic lines are decidedly oval.

Though Halley's chart gave the declination in the way most convenient for the mariner, the isogonic lines give no immediate picture of the distribution of compass direction. This is better shown by magnetic meridians, lines drawn so that at each point along them they have the compass direction there. Such geomagnetic meridians were first drawn in 1817 by Thomas Yeates; in 1836 the French admiral Duperrey showed such lines drawn on two circular maps, each showing one hemisphere. They pass from the south to the north magnetic pole, like the lines drawn by Gilbert on his globular lodestone; but they are less regular, and not great circles, as Mercator had supposed. The lines of equal dip cross them nearly but not exactly at right-angles. Another sign of the moderate irregularity of the earth's magnetism is that the line joining the north and south magnetic poles misses the earth's centre by about 700 miles.

These magnetic poles lie in cold regions difficult of access, and have seldom been visited. Their positions have mostly been inferred from the trend of the declination and dip at a distance. The recent flights of the British aeroplane *Aries* over the north polar region have revealed an error of about 100 miles in the charted position of the north magnetic pole.

(*To be concluded*)

The Bookshelf

The Autobiography of Science. Edited by F. R. Moulton and J. J. Schiffers. (Doubleday, Doran & Co. 1945, New York, pp. 666, $4).

THERE is a vast difference between "reading literature" and "reading *the literature*"; the fact that there are innumerable literary anthologies whereas very few anthologies of scientific literature have been compiled is one expression of that difference. The words of more than a hundred scientists contribute to this volume, and the passages selected have been chosen for their readability and because they represent "turning points" in the history of science. The authors have provided quotations long enough to give the substance as well as the occasion of the great ideas in science; in order to find the space necessary to this aim they have discarded developments in favour of beginnings.

The editors maintain that "good science makes good reading", and their case is supported by most of the excerpts in the book. The contention is more difficult to substantiate with modern scientific literature, in which formulae, equations and graphs are indispensable but detract from readability, using that word in the literary sense applicable to an anthology. The gulf that now divides scientific language from the common tongue is very deep and wide; in fact Moulton and Schiffers do not attempt to bridge it—instead they go round it, quoting, for instance, from Einstein's own *popular* exposition of relativity, in sharp contrast to Newton's words which they take direct from the *Principia* and *Opticks*. Again, E. O. Lawrence's lecture from which an excerpt is given is a *popular* lecture, and the same adjective is to be applied to most of the material of recent origin.

This is a book that will be pleasant to dip into from time to time. In some respects, too, it will be convenient for reference; for example, Mendel's "lost paper" (translated by Bateson) is printed in full, as is Malthus's essay on population. Many points of information which one gets at second (or twenty-second) hand from encyclopædias—Lucretius's ideas about atoms, da Vinci on aviation, the hypotheses of Galileo and Copernicus—can here be read as they were originally stated or proposed. WM. E. DICK.

Aviation. By H. E. Wimperis. (Oxford University Press, 1945; pp. 177; 3*s*. 6*d*.).

To be initiated, the name of the author of this little book (the latest in that excellent series, the Home University Library) will be sufficient recommendation. As Director of Scientific Research at the Air Ministry during the critical years from 1925 to 1937 he was responsible for inaugurating many of the research programmes which have led to the developments of to-day, and on the strength of this experience alone any book of his must command attention. However, this particular one is not merely an authoritative report, but is, moreover, an eminently readable and comprehensive account of aviation in its broadest aspects.

The book follows an extremely logical pattern. Starting off with an account of the growth of flying, the reader is brought up to the problems facing us to-day, in an exposition of technicalities in simple language, which is a model of its kind. Apart from another chapter on "Flight and Physiology", the rest of the book deals with what might be referred to as the social implications of aviation; herein lies its real value.

On all sides the call for more research is heard, and controversy rages as to the form of organisation science should take. Much can be learnt from the existing organisation of aeronautical research, and a valuable chapter is devoted to this subject. Critics of planned science under State direction would do well to ponder on two statements of Mr. Wimperis. Called in to advise the Australian Government on the establishment of an aeronautical research organisation, the author presented a report recommending the expenditure of £140,000 and the immediate appointment of the staff. This was adopted within 24 hours of the report being received—hardly the "dead hand of bureaucracy"! Discussing the development of Radar, he mentions the beginning of the research programme as long ago as 1934. One wonders whether the Battle of Britain would have been won without the result of this piece of planned science.

Interest in aviation at present is centred on three main aspects—the role of the aeroplane in war, the contribution of air transport to trade and social intercourse between nations and, what is really a synthesis of these two, its implications with relation to world security and peace. Though written before the advent of the atomic bomb, the discussion in the chapters covering these aspects is not dated, but is, in fact, grimly underlined by what happened at Hiroshima.

Some useful statistics are given in the chapter on Civil Aviation, and while not everyone will agree with the suggested organisation of overseas airlines the points of view put forward must be known, if the difficulties which arose at the recent Chicago conference are to be appreciated.

Finally, the alternative methods of ensuring world peace by air power are dealt with. Ironically enough, the combination of atomic bomb and the aeroplane may make some form of international peace force a reality. The author ends on a timely note, pointing out that while science destroys, it also saves far more at the same time; neither is its destructive power the sole fault of the scientist "to ensure that such inventions shall be rightly used . . . is the responsibility of all citizens."

The reviewer more than recommends this book. He would demand that everyone taking an intelligent interest in world affairs should read it. J. BLACK.

Time, Knowledge and the Nebulae. (By Martin Johnson; Faber, pp. 189 12*s*. 6*d*.)

DR. Johnson gives us an essay on the development of the relativity theories of Einstein and of Milne, with particular reference to the logical status of the concept of "time" fundamental to Milne's theory. In the further development of Milne's theory two distinct time scales are introduced, and Dr. Johnson apparently wishes to have us believe that there are still further physical interpretations which may be put on the word "time" in addition to concepts associated with the psychological consciousness of the sequence of events. Dr. Johnson claims that his is an introductory discussion of the subject, but this is not a claim which can be substantiated. The tone of the book is confused, for his exposition wavers between the most elementary of points and the discussion of features of relativity theory which are only thoroughly understood by the very small number of specialists who have a clear understanding of all the theories of relativity now extant.

The unsatisfactory quality of the book may be illustrated by the purely personal experience of the reviewer. Some years ago he was sufficiently familiar with Einstein's theory of relativity to pass an examination in it: since then he has endeavoured to keep abreast of the general development of fundamental physics, including the kinematical relativity of Milne. This experience should place him, not in the class of specialists in relativity, but in the class of those who should be capable of understanding the thesis of a general essay on relativity. His failure to gain any clear insight into the intention of Dr. Johnson's book may be due either to his own obtuseness or to a failure on the author's part to explain what he is driving at. The reviewer makes bold to suggest that the latter is the case, and that this book is unlikely to be at all intelligible to anyone less versed in relativity theory. Certainly Dr. Johnson's exposition of Milne's relativity theory is far less clear than Milne's own technical account. D. S. EVANS.

Physical Planning. Edited by I. R. M. McCallum, (London, Architectural Press, 1945; pp. 296+40 plates; 21*s*.).

THE 26 chapters of this symposium cover aspects of town and country planning as widely different as ecology, publicity, minerals, agriculture, housing, transport and leisure. Each chapter is written by a recognised authority. Outstanding, because they deal with topics not usually included in this kind of book, are the contributions of R. E. Dickinson (on ecology) and Professor H. H. Read (on minerals). The book concludes with a valuable bibliography.

Far and Near

Scrub Typhus Vaccine

LAST month it became permissible to refer to the vaccine successfully used to protect our troops in S.E.A.C. against scrub typhus. The discovery and production of this vaccine represents a major triumph for war-time medical research. Scrub typhus was one of the most serious risks to life and military efficiency faced by our troops in the Far East. Without the vaccine it usually incapacitates a sufferer for at least three months, and as many as 20 per cent of sufferers may die, although the average mortality is about 5 per cent.

The best name for the disease is "mite typhus". The name "scrub typhus" often given to it is not so satisfactory because is has no essential connection with scrub vegetation. The carrier is the larva of one mite which transmits the disease to man, and the climate and vegetation operate only indirectly in controlling the life and distribution of this mite. Dutch workers in the Netherlands East Indies and also some modern American experts believe that the larvae of ticks are more efficient transmitters of the disease than the mites.

The larva of the mite which transmits mite typhus measures only about one hundredth of an inch long, so that the presence may not be detected until the effects of the bite (it is supposed only to bite once in its lifetime) appear. There is an incubation period of 7-21 days. A sore, about 2-3 millimetres in diameter may appear on any part of the body at the site of the bite, which develops into a small ulcer. Fever develops with headache and pains in the limbs and loins; a rash appears on the trunk from the fourth to the seventh day, although this may be difficult to see on sun-tanned or coloured skins.

Some details about the making of the vaccine were given in an article published in *The Lancet* (Sept. 8, 1945, p. 308). By December 1943, mite typhus had become a major factor in military operations in the Far East and work was undertaken on the preparation of a vaccine against it. Previous attempts to make a vaccine by the method, often employed, of cultivating the disease organisms in the yolk sacs of hen's eggs, had not been successful But workers at the National Institute of Medical Research, Hampstead, found that the *Rickettsia* that causes scrub typhus could be recovered in abundance from the lungs of cotton rats infected through the nose They found that a vaccine made of killed *Rickettsiae* protected mice sufficiently to justify a trial of the vaccine on human beings and a small field trial of the vaccine was arranged in the Far East. Military plans, however, could not wait for this trial to be completed and it is to the great credit of the War Office Directorate of Pathology that they decided to proceed forthwith with the preparation of the vaccine on a large scale. By April 1945 suitable buildings had been erected for the manufacturing project, known as "Special Operational Store—Tyburn", which was given top priority. The Air Ministry arranged for the transport of cotton rats (*Sigmodon hispidus*) from America; volunteers, who included doctors, laymen, Army medical officers, research workers, soldier and A.T.S. girls, undertook the considerable risks of infection associated with work on vaccines of this type. With the co-operation of the War Office, the Medical Research Council, the Ministry of Supply, the Wellcome Foundation and the Air Ministry, the vaccine was prepared. The aim then was to achieve simultaneously a field trial of the vaccine on a large scale and the immunisation of as many troops as possible. The results of the trial are not yet available, but it is clear that everyone concerned is to be congratulated on the speed and efficiency with which a difficult operation was performed.

Film and Science Education

THE struggle with words still takes place. Teachers, scientists, and film directors still debate the true place in education of the science film. In shape the argument is not new, even if the technical possibility of the use of such films is recent. One early authority on education stated "I maintain that it is not only possible for one teacher to teach several hundred scholars at once, but that it is also essential." Thus wrote Comenius in respect of his invention of the monitorial system of teaching. Others to-day assert the possibility of greater "productivity" on the part of the teacher by the introduction of modern mechanical aids.

The very good attendance at the week-end conference in Huddersfield promoted by the Scientific Film Association last month demonstrates that at least 120 people in this country are prepared to travel in discomfort and spend two days discussing scientific films—and this mainly in support of an idea whose full fruition is still awaited.

The discussion continues. The teachers, in general, take a stand on behalf of the personal relation between pupil and teacher; the facts presented by films are to be left for the teachers to interpret. The film director sees his product as a whole, the facts needing to be drawn together under his hand. Other difficulties need also to be resolved. Who should pay for the films?—for it is tacitly agreed that films are necessary. How is it possible to escape the Scylla of the Rank organisation, and the Charybdis of the Ministry of Education?

Granted there is an absolute shortage of teachers in face of our great educational needs; in respect of schools it is obvious that all mechanical contrivances of value must be used. And there must be added the needs of industry for training and reconversion. All this demands the most critical examination, by teachers and film makers alike, of possibilities and methods.

It is premature to classify the types of scientific film for use in education, just as it is premature for the interested parties to define their attitudes too rigidly in advance. The vast evolutionary expansion is before us and its phyla are still dim. The need of the times is to speed up the evolutionary process, to experiment on a large scale.

This reverts to a problem in civics. Perhaps the Mayor of Huddersfield or the local M.P., Mr. Mallalieu, both of whom gave their support to this meeting of the Scientific Film Association, may be prepared to go a step farther?

The Radio Proximity Fuse

NEWS about the radio proximity fuse that stepped up the efficiency of A.A. fire towards the end of the war was released last month. The clockwork fuse, upon which reliance had to be placed for the greater part of the war, was set before firing to go off at a given moment when it was predicted that the shell would be close to its target. With the radio proximity fuse, operated by means of a small radio set incorporating both transmitter and receiver, if the shell passes within a certain distance of an aircraft it will explode.

The original conception was British, and the earliest researches were carried out in Government research extablishments. Our ideas were passed to the Americans in 1940 and the fuses actually used in the war were all of American design and manufacture. The original idea is attributed to Mr. W. A. S. Butement (designer of the CHL radar unit), then with the Air Defence Research and Development Establishment of the Ministry of Supply, and Mr. E. S. Shire. When the fuse came into production it was decided that naval A.A. should have prior claim, and these fuses came into operational use in the British Navy towards the end of 1943. The startling increase in efficiency in shooting down flying bombs that came in August 1944 was due almost entirely to the use of these fuses. In the fighting on the Continent the fuse appears to have been held back until the critical days of the German offensive in the Ardennes.

Reform of Scientfic Publications Proposed

THE 20th—and largest—conference of ASLIB (Association of Special Libraries and Information Bureaux) opened with an address from Professor J. D. Bernal on the subject "Information Service as an Essential in the Progress of Science". The experience of war, he said, had taught a very large number of scientists the vital place of an efficient information service. He discussed the problem of the alarming increase of literature in all subjects, while the individual worker's capacity to absorb remained constant. Despite alarming deficiencies, the information services of the war ministries were invaluable in winning the war. The opportunity created by the war for reorganisation of scientific publications should be seized, and he went on to discuss proposals for co-ordinating national

centres of scientific publication through an international body; he put forward a detailed scheme of publication similar to that suggested by N. W. Pirie in *The Journal of Documentation* (mentioned in the last issue of DISCOVERY).

An informal discussion in the evening dealt with the actual problem of the Reform of Scientific Periodicals. It was proposed that (*a*) papers should be issued individually in standard format by a central distributing authority, (*b*) the scientific societies would keep their publishing right and editorial boards and (*c*) each paper should be adequately abstracted immediately and, if necessary, from several points of view. After considerable argument from a representative cross-section of research workers, librarians and readers, it was decided to appoint a committee of 3 ASLIB members and 3 members of Association of Scientific Workers to examine and push the proposals without delay.

The full report of the proceedings will be published shortly; the price to non-members will be 6*s*.

One of the proposed "geological monuments". Perched erratic block nea Austwick, West Riding. A block of Silurian rock (greywacke) deposited on the surface of Carboniferous limestone by a glacier during the Ice Age. The limestone has weathered except under the block

Geological Reserves

THERE is no lack of propagandists to make out an eloquent case for nature reserves. Far less familiar, even among scientists, is the idea of geological reserves and because the concept has not been brought to the notice of the British public except through the medium of papers with limited circulations, it is still very far from receiving popular support. It is to be hoped that the geologists associated with the report entitled *National Geological Reserves in England and Wales*, prepared by the Geological Sub-Committee of the Nature Reserves Investigation Committee, and published last month (price, 1*s*. 6*d*.), will not rest content with an appeal that is only likely to reach the already converted; support from far outside that small and very select circle is clearly necessary before the committee's recommendations can have any chance of adoption.

In his foreword, Sir Lawrence Chubb makes the point that many of the areas which should be protected for geological reasons, have striking scenic beauty. Areas of that kind are probably in very much less danger of being spoiled than are many other geological features which should be preserved but which have no picturesque appeal. Of the existence of these features there is as yet not even public awareness.

The report classifies geological reserves into four categories. The first of these are called *geological conservation areas*, which the report describes as large-scale physiographic features and areas containing many items of geological that should be preserved. An example is the coastal strip in Dorset, stretching from Mupe Bay to White Nothe, a classic district for geological study. Most of the areas in this category are scenically beautiful, but geological grounds are the sole reason for their inclusion in the list. It is recommended that working quarries in these areas should be registered, and that permission from an appointed authority, advised by a scientific panel, should be necessary before new quarrying could be undertaken. The next category are *geological monuments*—small-scale geological features and geological sections of outstanding interest. These should be permanently protected and kept in a good state of preservation. The erratic block in the photograph is an example of the kind of feature to be preserved as a geological monument; others suggested in the report include the site of the discovery of the Piltdown skull at Fletching, near Lewes, and the fossil forest at Lulworth.

Controlled sections provide the third category mentioned in the report. Here the committee urge that natural geological sections, and artificial sections that are in a state of disuse, should be controlled for their scientific value in order to prevent them being irretrievably obscured by building, use as rubbish dumps, etc. Permanent upkeep of many such sections would be impracticable, but it is necessary that these sections should always remain accessible. Some of the sections would bear clearing of rubbish, but that could be done after control had been secured. The fourth category contains what are called *registered sections*. Exceptionally interesting sections that are being used or worked should be listed and kept under observation by an appointed authority. The owners or lessees should be required to give notice of their intention to cease operating, and then the sections could be considered with a view to transferring them to the "controlled section" category. Where it is possible that a unique section runs the risk of being completely removed, the firm concerned might be persuaded to preserve a typical column of strata.

The number of reserves envisaged is not large, amounting to less than four hundred items for the whole of England and Wales. These items are listed in the report county by county; 72 conservation areas are suggested, and the geological monuments total 48, while the number of sections that should be controlled or registered are respectively 198 and 73.

Science for the Citizen

WHAT is "Science Magazine" intended to be? The prelude to the series was a discussion as to what it *might be*, but the expectations then aroused are not being satisfied. Perhaps if we were told what it *is not* we could work out its intentions by the process of elimination. One such clue was given in the second issue when it was stated categorically that it was not a news magazine nor a Brains Trust. The programme itself certainly proved that it was not the former; had topicality and news value counted for anything the atomic bomb and radar would have been given pride of place, but in fact there was nothing about the first, and in the breathless jockeying for a place near the microphone—five scientists had to have their say in 30 minutes—the contribution of Dr. W. B. Lewis, which promised to have great interest coming from one of radar's most important researchers, was somewhat hemmed in and could not have received the close attention it deserved. Which was not Dr. Lewis's fault.

Two sparks of life have appeared in "Science Magazine"—the talks by Drs. A. S. C. Lawrence and Rapkine. If someone with good lungs will blow long enough the sparks may produce flame.

The radar item in "Science Magazine" seemed little more than a nibble at a big story, particularly in contrast to the dramatised story of radar produced by Cecil McGivern. This has already been broadcast a second time; it obviously merited a repeat. The broadcast of "Radar" on August 20 ended two minutes ahead of schedule, and the hiatus was filled not with the usual stop-gap gramophone record but with silence—two minutes

silence in which there was time for the greatest public tribute ever paid to British scientists to sink in. Each step in radar development was described to bring out the full war-time partnership that existed between scientists and airmen. Each new radar device was shown as the answer to a specific operational need, and the new techniques of interception and bombing that each device made possible were sketched very clearly. The introduction of GCI, for instance, was related to our still vivid memories of newspaper headlines that announced more German night raiders being destroyed over Britain as the spring of 1941 wore on; in the same way Cecil McGivern connected "Gee" with the first 1000-bomber raid, and H2S with Hamburg's destruction. More vividly than any other account of radar that this reviewer has met, this broadcast did full justice to the scientists' contribution to the winning of the Battle of Britain and the Battle of Germany.

The Association of Scientific Workers have just published a new edition of the "Graded List of Scientific Films" prepared by their Scientific Films Committee. It costs 2*s.* 6*d.*

Science at the T.U.C.

THE Trades Union Congress is to set up a scientific advisory committee to assist the General Council and affiliated unions with information and advice on scientific problems. This was decided at the annual meeting. Speaking to the resolution—proposed by the Association of Scientific Workers and seconded by the National Union of Mineworkers—Professor P. M. S. Blackett said it was essential for the trade union movement to have the best possible scientific advice on the development of atomic power.

The establishment of a National Research and Development Council was called for, which would have power to direct and subsidise approved research and to control patents. Other resolutions that were adopted advocated an extension of industrial health research and the setting up of a university chair for the study of industrial diseases.

Correction

IN the last issue the diagram on p. 264 above the cloud chamber photograph was printed 90° out of true; the line of the α-particle should have been vertical, in alignment with the α-particle track shown in the photograph.

U.S. Radar Report

THE U.S. Government's report entitled *Radar. A Report on Science at War* has now been reprinted by the British Stationery Office and distributed in this country, price 1*s.* It is disappointing that no similar printed document compiled from British sources of information has appeared at the time this issue goes to press.

Night Sky in November

The Moon.—New moon occurs on November 4d. 23h. 11m., U.T., and full moon on November 19d. 15h. 13m. The following conjunctions take place:

November				
2d. 12h.	Jupiter in conjunction with the moon,	Jupiter	4°	S.
2d. 20h.	Venus ,,	Venus	4	S.
6d. 17h.	Mercury ,,	Mercury	5	S.
23d. 13h.	Saturn ,,	Saturn	2	S.
23d. 03n.	Mars ,,	Mars	0.6	S.
30d. 05h.	Jupiter ,,	Jupiter	4	S.

The Planets.—Mercury sets about half an hour after the sun during the month and is unfavourably placed for observation. The planet attains its greatest easterly elongation on November 17 and is stationary on November 27. Venus is a morning star, rising at 4h. 44m., 5h. 30m., and 6h. 19m. at the beginning, middle and end of the month respectively. Mars, in the constellation of Cancer, rises at 21h. 13m. and 19h. 49m. at the beginning and end of the month respectively; the distance of the planet from the earth varies between 97 and 74 million miles during this period. Jupiter, in the constellation of Virgo, can be seen in the morning hours, rising at 4h. 37m., 3h. 58 m. and 3h. 14m. at the beginning, middle and end of the month respectively. On November 1 the planet is 590 million miles from the earth and on November 30 the distance has decreased to 565 million miles. Saturn, in Gemini, can be seen late in the evening, rising at 21h. 12m., 20h. 16m., and 19h. 16m. at the beginning, middle and end of the month respectively. The planet is stationary on November 6. During the month the distance of Saturn from the earth varies between 815 and 776 million miles.

Times of rising and setting of the sun and moon are given below, the latitude of Greenwich being assumed:

November	Sunrise	Sunset
1	6h. 53m.	16h. 35m.
15	7h. 17m.	16h. 12m.
30	7h. 41m.	15h. 55m.

November	Moonrise	Moonset
1	2h. 44m.	15h. 54m.
15	14h. 51m.	1h. 02m.
30	2h. 48m.	14h. 33m.

Amongst the interesting objects which can be seen with a small telescope may be noticed the Great Nebula in Orion which surrounds θ Orionis, the middle star of the sword of Orion. This nebula, unlike the Great Nebula in Andromeda to which reference was made in last month's DISCOVERY, consists of an enormous cloud of cosmical dust which is excited to luminosity by hot stars in it. It is far away from the stars we usually see in Orion, being about 600 light-years distant from us. Even binoculars will show this object on a clear night, and those who possess a pair should look at this interesting nebula.

M. DAVIDSON, D.SC., F.R.A.S.

JUNIOR SCIENCE

About Atoms—I

SINCE the atomic bombs were dropped on Japanese towns you will have heard much about atoms. I am sure you know by now that an atom is supposed to look rather like a very small solar system in which the place of the sun is taken by a *nucleus* which has a positive electric charge and around which negatively charged *electrons* circle like planets around the sun. I told you about this little solar system some months ago when we discussed light and colour. Now all this seems to be very simple, though a bit strange, until we remember that nobody has ever seen an atom—in fact we will never be able to see one even with the most powerful microscopes.

How, then, do we know that atoms really look like the sun and the planets? You could, for instance, find out whether there is an obstacle in a dark passage into which you cannot see by throwing tennis balls into it. If you have thrown many balls and none has come back, you conclude that the passage is free. But if some of the balls bounce back, you know that there is something inside the passage. By carefully noting the angle at which the tennis balls come back, you could even guess as to whether they have been hitting a plane or a curved surface; that means you could draw conclusions as to the shape of the invisible object. This is roughly the way scientists have explored the structure of atoms. By bombarding them with a beam of positively charged particles and observing in which way these particles were deflected on encountering atoms, physicists have been able to calculate that each atom must consist of a minute centre—the nucleus—which is positively charged and which is surrounded by a negative electric charge which is less densely packed than the positive charge in the centre.

From these and similar observations the idea of the miniature solar system was derived.

Light, as we have seen, is generated when an electron which has been pushed out of its proper orbit around the atomic nucleus falls back into its normal position, and by a very thorough study of the different wavelengths of light which are emitted by the various atoms we have learned more and more about the structure of the electron orbits around the nucleus.

It is, however, necessary to remember that the miniature solar system is only a model invented to help us visualise the rough outline of atomic structure. It would be a rash conclusion to believe that an atom bears any but the remotest resemblance to the sun with its planets. Why such a conclusion is not permissible I will tell you next month. K.M.

Printed and published in Great Britain by Jarrold & Sons, Ltd., The Empire Press, Norwich.

vember

occurs on
.T., and full
. 13m. The
lace:

piter	4°	S.
nus	4	S.
ercury	5	S.
turn	2	S.
ars	0.6	S.
piter	4	S.

s about half
g the month
for observa-
its greatest
ber 17 and is
Venus is a
m., 5h. 30m.,
ning, middle
vely. Mars,
cer, rises at
he beginning
ectively; the
n the earth
million miles
in the con-
seen in the
h. 37m., 3h.
e beginning,
respectively.
s 590 million
November 30
565 million
n be seen late
. 12m., 20h.
e beginning,
respectively.
November 6.
ce of Saturn
en 815 and

g of the sun
the latitude
ned:

Sunset
16h. 35m.
16h. 12m.
15h. 55m.

Moonset
15h. 54m.
1h. 02m.
14h. 33m.

bjects which
lescope may
la in Orion
the middle
This nebula,
Andromeda
ade in last
ists of an
l dust which
ot stars in it.
s we usually
0 light-years
oculars will
r night, and
ould look at

D.SC., F.R.A.S.